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To D^r. David Badham
with the Author's best Compliments

RESEARCHES

ON THE

DEVELOPEMENT, STRUCTURE, AND DISEASES

OF

THE TEETH.

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THE TEETH.

BY

ALEXANDER NASMYTH, F.L.S. F.G.S.

MEMBER OF THE ROYAL COLLEGE OF SURGEONS, LONDON; FELLOW OF THE ROYAL MEDICAL AND CHIRURGICAL SOCIETY.

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TO

ROBERT NASMYTH, ESQ.

EDINBURGH.

MY DEAR ROBERT,

As there is no one more capable than yourself of fully appreciating the beauty and importance of the subjects discussed in the following pages, and none so likely to regard their defects with an indulgent eye, it is to you that this work is dedicated by

Your affectionate Brother,

ALEXANDER NASMYTH.

London, George Street, Hanover Square,
May, 1839.

PREFACE.

The teeth may be regarded in the first place as the armoury of the mouth; and in the second, as the instruments by which the process of assimilation is commenced. They assist in seizing, dividing, tearing, and masticating the substances which the diversified surface of the earth, the fathomless depths of the ocean, and the boundless expanse of atmosphere, afford in infinite variety as materials for building up the physical frame-work of animated existence. They present themselves as appendages to the skin, to the products of which in some of their modifications they bear a great resemblance, whilst in others they resemble true bone. The varieties which they present throughout the range of the animal kingdom correspond to the infinite diversities in the functions they are required to perform; and wonderful are the minute and perfect adaptations which they present in various animals

to the wants and instincts of the latter. Indeed, from their peculiar conformation, they indicate so exactly the type of animal to which they belong, that they are found to furnish the best characteristic marks by which to classify the members of the animal kingdom. Their importance, therefore, in a scientific point of view, is very great, the aid which they afford to the naturalist being precise and definite: they have held a prominent place in all classifications of animals, and Brisson adopted them exclusively as his guide in this department of his labours. Such is the beautiful harmony of Nature, that the information acquired by means of these organs puts us at once in possession of a knowledge of many of the anatomical peculiarities and distinguishing habits of the animals to which they respectively belong. Moreover, the enduring nature of the materials which enter into their structure cannot but give them additional value in the eyes of the Geologist.

Cuvier, whose scientific research was at once remarkable for its elevation, and for the grandeur and breadth of contemplation which it displayed, has widened by his profound labours the field of physical philosophy; he has lit torches in the abyss of time, to guide us in our inquiries into the past, which were they zealously prosecuted, ' man, to whom only a momentary sojourn on earth has been accorded, would have the glory of unfolding the history of the thousands of centuries which have preceded

his existence, and of the millions of beings who were not his contemporaries."*

Profundity and clearness are the characteristic qualities of this immortal philosopher, and are alike displayed in his researches themselves, and in the deductions which he has drawn from them. In the following passage we have, as it were, an outline of the system which all his labours tended to establish :—" If the intestines of an animal are so organised as only to digest flesh, and that recently killed, it is necessary also that its jaws should enable it to devour its prey; that its claws should be capable of seizing and tearing the latter; its teeth of cutting and dividing it; its organs of motion of pursuing and reaching it; its organs of sense of perceiving it at a distance: it is necessary even that nature should have placed in its brain the instinct necessary for teaching it to hide itself and entrap its victims."

From amongst the several links of this harmonious chain of organs and properties, all adapted with wonderful fitness to the purpose in view, Cuvier has fixed on the organs of mastication as the truest and most comprehensive marks of the respective types of the different members of the animal kingdom.—Can we hesitate to pursue such an inviting path, pointed out to us as it is by such an exalted master?

F. Cuvier mentions " l'emploi des dents comme un

* *Cuvier sur les Ossemens Fossiles. Discours Prelim.* p. cxl.

des signes les plus certains de la nature des animaux, et des rapports qu'ils ont entre eux; signes qui sont un des fondemens de la science, puisqu'ils sont de sa methode, ou autrement de l'ordre des faits ou de leurs liaisons, conditions indispensables à l'existence de toute science."

In the sequel to the present work it will be shown that, besides the general conformation and external appearance of the teeth, another distinctive peculiarity by which the Almighty has characterised the different members of the animal kingdom exists in their beautiful internal, minute, and hitherto hidden organisation, which further demonstrates in a most striking manner the harmony of all created existence.

In man the mouth is as important as in the lower animals, for the performance of functions which are common to both, and has also other offices corresponding to the intellectual qualities, with which he is exclusively endowed. With him, too, it is the porch of assimilation, but with him alone it serves for the expression of mental operations—the elevated characteristic of his race. He not only performs mastication by its means, but accomplishes with its aid the emission of articulate sounds; communicates his ideas to his fellow-men, receiving information conveyed in the same manner in return; and thus are means furnished for the infinite progress and improvement of mankind. By the endowment of speech man is enabled to command and direct the beings around

him, and to bring to bear on a single point the will of a whole race. The teeth are of essential importance in the exercise of this faculty, for the eloquence of the statesman would be powerless, and the force of his arguments unavailing, if they were deprived of the sonorous utterance imparted to them by these organs, without which, too, the warrior's exhortation and command must lose their electrifying influence.

The Historical Introduction with which the present work commences, occupies a much larger space than I at first intended to allot to it: its length is owing to the variety and importance of recent investigations in this department of science, conducted principally by Swedish and German anatomists. It still, however, might have been enlarged in that part which treats of old writers; but I have been induced to omit many of their statements, as being more curious and fantastic than practically valuable: the labours of many modern writers of ability might also be added to it, but not with much advantage. From the very commencement of it the reader will be struck with the conflicting nature of the evidence which it contains on even the most elementary points. I am inclined to think, however, that these discrepancies have not their origin so much in absolute error, or in defect of observation, as in the constantly varying condition of the parts which have been described, and in the diversity and imperfection of the means which have been used for their

examination. Without recurring to such an explanation as this, it is impossible to conceive how such men as Hunter, Cuvier, Bichat, and Blandin, for instance, can often flatly contradict each other. Those who have hitherto published the results of their experiments in this department of anatomy, have, for the most part, omitted to give an account of their methods of investigation, and of the species, age, &c. of the subjects which have been submitted to examination; thus rendering it impossible to test the accuracy of their facts, and to discover the source of fallacy either in the new views, or in those which had hitherto been current.

I have endeavoured to conduct my investigations on a scale which I conceived commensurate with the importance of the subject; and in detailing the results which I have arrived at, I shall give as careful a description as possible of the nature of the experiments, dissections, or observations which led me to them. The substance of what I have to offer will go to prove, I think, a greater degree of simplicity and uniformity, than has hitherto been suspected in the organisation of these structures.

The great advance which has of late years been made in the science of optics, has enabled the student of minute anatomy to penetrate into new regions,—has unfolded, as it were, new provinces of animated existence to the gaze of the zealous and delighted inquirer. The urgent demands made by geologists, for microscopic sections of dif-

ferent organised structures, have been so well responded to by those who prepare them, that various structures have lately been brought within the range of our vision, of which the nature had hitherto been wrapped in obscurity, from our not having possessed the means of ocularly examining them. To these two causes united we may trace the splendid contributions with which science has lately been enriched; and it is principally on account of the interest excited by the writings of one of the labourers with the microscope, whose observations were made on the delicate sections above alluded to, that I have been induced to collect and publish my researches on this subject.

In 1837, I learnt that Professor Retzius of Stockholm had published a very interesting series of microscopic investigations on the structure of the teeth, and I then made every exertion to obtain his publication, but without success. I first saw it in April 1838, when I was favoured with a loan of it, by my learned friend, Dr. Grant.

The interest excited by the new views of this intelligent and industrious Swedish physiologist, induced me to resume a course of investigations on all the points connected with the structure of those organs, and I immediately announced my intention of publishing on the subject, and pursued my investigations with assiduity. Not less than five years ago, I made many observations on the structure of the teeth, and saw at that time their striated appearance; but being unable satisfac-

torily to explain this, and knowing that it had already been recorded by Cuvier, I did not attach sufficient importance to it, as it did not then seem to me to be likely to lead to any practical results. My observations were shortly afterwards interrupted, owing to the imperfections of the microscope which I then used, and to the difficulty I experienced in making suitable sections of the teeth.

I did not at first intend to publish the whole of Retzius's account of the tubular system in different animals, but I at length determined to do so, as I found that it could not be divided without injury to the whole, and that, moreover, I should frequently be compelled to refer to almost every part of it.

Those who contemplate the teeth merely as ornaments, or consider them in no other light than as the active agents at a feeding trough, or as the formidable weapons of the wild tenants of the forest, will, doubtless, regard the details of Retzius as irksome and tedious; but he who with ardour and admiration tracks the steps of Nature through the regions of Zoology, will welcome with delight a full description of these new researches; he will recognise at once their importance, and cannot fail to be struck with the unostentatious manner in which a great mind has opened to the world a new field of exertion, foreseeing its value to the student of Geology as well as of Natural History. But I have been still further induced to publish the researches of Retzius, from having

myself made numerous observations and experiments on the same subjects, which I hope will be found to illustrate some of them, and to carry out others to very interesting and original conclusions.

The importance of the study of Odontology in a zoological and geological point of view, has induced me to form as complete a collection as possible of microscopic preparations of the teeth of the various classes, both living and extinct, of the animal kingdom. From these I intend, in the course of the present work, when treating of the structure of the teeth, to make a selection calculated to serve as an index of the type of any animal. This part of the work I think will prove of much use to the Geologist, in enabling him to state to what class of animal any tooth, or fragment of tooth, belongs.

All must be fully aware of the importance which the study of the teeth assumes from a pathological point of view; but, generally speaking, many of the maladies incident to them seem to be overlooked. I shall therefore attempt, in the course of this work, to describe fully their diseases, and to ascertain their source, with a view to the alleviation of suffering from symptoms, which often appear to be as anomalous as they are distressing.

*** The continuation of this work will appear in a short time. The next parts will contain an account of the developement and structure of the teeth. The four plates, C. 1 to C. 4, at the end of the present part, form the commencement of a series of plates illustrating the structure of the teeth.

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OF

HISTORICAL INTRODUCTION.

HISTORICAL INTRODUCTION.

It is at all times instructive and of great utility to trace the progress of any branch of science, and as much importance is always justly attached to priority of information, as marking industry and activity of research, it behoves us, in the first place, to give a condensed view of the progress of knowledge respecting the teeth. This will enable us to judge what departments have hitherto been principally defective, and have remained to be elucidated by present or future researches.*

We learn from Herodotus that amongst the Egyptians at a very remote period, the care of the teeth was assigned to a particular class of persons; but respecting their anatomical knowledge, or proficiency in their art, we have no information. Of the views entertained of the physiology and pathology of these organs in Greece before the time

* In compiling the following Historical Sketch, I have consulted the works of original writers on the subject, and have derived much general assistance from Blandin's excellent work on the teeth, and from the late remarkable publication of Professor Retzius of Stockholm, whose ingenuousness in acknowledging the merits of preceding inquirers cannot be too much applauded. In collating the different accounts which have appeared of his Researches with the original Swedish work of Retzius, entitled "Mikroskopiska Undersökningar öfver Tänderncs särdeles Tandbenets, struktur: Stockholm, 1837," I have received valuable assistance from my learned friends, Dr. Minton and Dr. Bialloblotzky.

of Hippocrates, we know but little, except that they are embodied in the works of the latter. HOMER calls the teeth "little barriers opposed by nature to the unruliness of the tongue, and to the abuse of speech." He is fond of designating them as forming a wall or fence (ερκος οδοντων.)

THE views of HIPPOCRATES, who lived between three and four hundred years B. C., respecting their origin and formation, are extremely crude and fantastic. He says, "There is a glutinous increment from the bones of the head and jaws, of which the fatty part is dried by heat and burnt up, and the teeth are made harder than the other bones, because there is nothing cold in them." He goes on to say, that in the fœtus they are nourished by the food of the mother, and after birth by the milk which the infant sucks from the breast. He calls the wise teeth σωφρονιστηρες, and holds an opinion, which several authors have maintained after him, that to have a great number of teeth is a sign of longevity.

ARISTOTLE was so ignorant of the anatomy of these parts, as to assert that man has more teeth than woman, and that this difference is observable between the sexes in various classes of animals, as for instance in sheep, goats, pigs. All viviparous red-blooded animals have, he says, teeth; but all have them not in both jaws. Animals with horns, he continues, have no teeth in the front of the upper jaw, and in some without horns this peculiarity is observed, for example in the camel. He states that only the front teeth change in man; that the molars are not shed in any known animal; that the pig loses no tooth; that the age of animals may be determined by their teeth; and that they become discoloured in course of time,

except in the horse, whose teeth are whitened by age. He considers that the difference betwixt bone and tooth consists in the circumstance, that the teeth increase in length during life, whilst the bones have a determinate limit to their growth.

We may judge of the knowledge of these organs possessed by Aretæus, from his assertion that the cause of the tooth-ache is only known to God. Pliny, who lived about four hundred years after Aristotle, does little more than repeat the doctrines of the latter, illustrated and embellished by various fables of his own. He mentions, however, the indestructibility of these organs, remarking that every other part of the bodies which were enclosed in the sarcophagi was destroyed, except the teeth.

In the second century after Christ, Galen, who had profited by the labours of his predecessors, more particularly of the Alexandrians, wrote a better account of the teeth than any which had hitherto existed. He teaches that they are formed during the period of gestation; but that they remain hidden in the alveoli until birth; that the molars of the upper jaw have three roots, those of the lower only two; and that the canine teeth had also received the appellation of ocular, (οφθαλμιχοι,) because branches are sent to them of a nerve, which distributes others to the eye. He has a long chapter on their forms, their functions, and their evolution, and does not hesitate to pronounce them true bones: *in ossium numero dentes habendi sunt, etsi secus nonnulli sophistæ arbitrentur.* He maintains that the teeth feel, and that he has proved this on himself: *quare utriusque doloris sensum expertus, alium quidem gingivis, alium ipsius dentis substantiâ esse non dubito.*

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Aetius says that the teeth are open at the roots, where they admit small nerves coming from the trifacial ; and that it is for this reason that they are the only bones which can become painful of themselves. He adds, that they grow till old age by the deposition in their interior of a nervous fluid ; but that at that period the process of. nutrition ceases, and they become loose, and finally drop out Rhazes described the process of dentition, but in a very incomplete manner. Abulcasis was the first who distinctly taught that teeth may be replaced either by other human teeth, or by artificial ones, made out of the bones of an ox.

Vesalius, the restorer of human anatomy, who was born about 1512, does not appear to have studied the teeth with the same attention which he devoted to the other parts of the body. According to him, the milk-teeth are the germs of the permanent teeth. The knowledge of these organs was greatly advanced by Eustachius, whose description of their number, different forms and varieties, leaves nothing to be desired : he compares their adhesion to the gums to that of the nails to the skin ; (*sicut cutis extremæ unguium parti adhæerescit ita gingivæ dentibus adjunctæ sunt ;*) and thinks with the ancients that their degree of hardness is proportioned to the ferocity of the animal. He made careful inquiries into their structure, in which he recognises two constituent parts, and compares the enamel to the bark of trees (*duplici substantia veluti arbores teguntur*). In an article on their developement, he describes the follicles, their vessels and nerves ; refutes the opinion of those who think that the roots of the milk-teeth are employed towards the formation of the permanent ones, and says that if the germs of the latter are not seen in the fœtus, *it is not that they do not exist,* but that they are

still too small to be recognised. That the teeth are nourished in a different manner from bones, he concludes, for this amongst other reasons, that their fractures cannot be made to unite. In his writings we find some details on their comparative anatomy, and he dwells more particularly on the teeth of the monkey. He relates a series of curious anomalies in the developement of the teeth, and speaks of a case of four successive dentitions.

Ambrose Paré, who wrote in the year 1579, gives a very correct account of the teeth, of their number, position, and uses, and of their attachments to, and connexions with, adjacent parts. He considers that the adherence of the teeth to the jaw is strengthened by a ligament which extends from the root of the tooth to the socket. "The teeth,"* he says, "differ from the other bones, because they have action whilst they chaw the meat, because being lost they may be generated, and for that they grow as long as the party lives; for otherwise, by the continual use of chawing, they would be worn and wasted away by one another." He adds, "You may perceive this by any that have lost one of their teeth, for that which is opposite to it becomes longer than the rest, because it is not worn by its opposite." Another of this writer's curious notions is, "that they have such quick sense, that with the tongue they might judge of tastes."

His cures for the tooth-ache are on a par with his ideas respecting the structure and functions of the teeth; but they are as rational as those of many practitioners of the present day, some of whom still firmly believe "that in the most grievous pains of rotten teeth, the thrusting of a hot

* *The works of that famous Chirurgeon Ambrose Parey.* Translated by Johnson. London, 1665, p. 125.

iron into their roots, or stopping them with cotton dipped in oil of vitriol, or aquavitæ, gives most certain ease." P. 283.

His opinion was, that the teeth, "like other bones, suppurated, and were subject to inflammation, the breeding of worms," &c. In such cases, he directs that a physician should first be consulted, and recommends "purging, phlebotomie, application of cupping-glasses to the neck and shoulders, scarification, washing the mouth with the juice of pomegranates, plantain-water, concocted vinegar, (for which he gives several nostrums,) narcotics to be dropped into the ear in order to stupify the nerve, leeches to the gums, and opening the veins under the tongue or behind the ears." He gives directions for the use of other similar remedies, which it is unnecessary to enumerate, as I have only given the above examples in order to show that this celebrated authority may be quoted for many strange practices of the present day. It is curious to notice that the peculiar remedies and treatment recommended by Hunter seem to have originated with Ambrose Paré, who was the first to describe the operation of transplanting, which, strange to say, found a strenuous advocate in our great physiologist. Ambrose Paré, however, only gives upon hearsay a case in which this operation was said to have succeeded.

In his chapter on operations, his directions are to a certain extent admissible, if it were not that he recommends interference where it is unnecessary. Within the last ten years I have known the very pelican of which Paré gives a drawing, used in London, and its propriety and efficacy asserted. His account of the operation of tooth-drawing is as follows:—"For the better plucking out of the tooth, the patient shall be placed in a low seat, bending back his head between the

tooth-drawer's legs; then the tooth-drawer shall deeply scarifie about the tooth, separating the gums therefrom, and then if spoiled, as it were, of the wall of the gums, it grow loose, it must be shaken and thrust out by forcing it with a three-pointed levatory; but if it stick in too fast, and will not stir at all, then must the tooth be taken hold of with some of the toothed forcipes, now one, then another, as the greatness, figure, and site shall seem to require. I would have a tooth-drawer expert and diligent in the use of such toothed mullets; for, unless one know readily, and cunningly how to use them, he can scarce so carry himself but that he will force out three teeth at once, ofttimes leaving that untouched which caused the pain." (p. 416.)

In the chapter of his work, "Of the placing of teeth artificially made instead of those that are lost or wanting," he says, "Teeth artificially made of bone or ivory may be put in the place of those that are wanting; and they must be joined one fast unto another, and also so fastened unto the natural teeth adjoining that are whole; and this must chiefly be done with a thread of gold or silver, or, for want of either, with a common thread of silk or flax, as it is declared at large by Hippocrates, sect. ii. *lib. de art. Sent.* xv."*

SCALIGER calls the teeth bone, *sui generis;* he denies that they have any proper sensation, and compares them in this respect to the nails. KERKRING, on the other hand, finds that they are perfectly analogous to bones; but he devotes only a very short space to them, and concludes by saying, "*De dentibus nihil dicam aliud quam nihil esse quod hic peculiariter sit commemorandum!*"

* The passage here alluded to I have not been able to find.

Malpighi says that the teeth consist of two parts, of which the interior, a bony lamella, is formed of fibrous and, as it were, tendinous hair, woven into a kind of net-work. *Dentes* " *duplici excitantur parte, quarum interior ossea lamella fibrosis et quasi tendinosis capillamentis, innaturam retis implicitis, constat.*" Anatome plantarum, Lugd. Batav., 1687, p. 37. In another place, he says, " *Completus et stabilis dens molaris ut plurimum binis pollet radicibus, quarum altera latior est et facta per longum scissione ejus compages manifestatur; ossea namque substantia tubulosa apparet qua dens compaginatus folliculum continet.*" (Opera Posthuma. Amstclod. 1698, p. 72.) On these passages Retzius observes, that the words in the former one, " *in naturam retis,*" show that Malpighi here alludes to reticular fibres of the tooth-bone, and that by the phrase " *tubulosa substantia,*" in the second one, he means the hollow tubulated roots. At page 71, l. c. he says of the incisor tooth, — " *sensim in cylindrum seu fistulam desinit, quæ intra mandibulam condita loco radicis inservit.*"—" *Totus tubulosus est, et folliculum continet.*"

The most valuable publication, however, of the seventeenth century on the subject of the teeth, is a paper of Leeuwenhoek, in the Philosophical Transactions for 1678, in which we find the following remarkable passage: —" I have some time since applied a glass (esteemed by several gentlemen who had tried it a very good one) to observe the structure of the teeth and other bones, which both to them and myself also then seemed to consist of globules; but since then, having drawn out one of my teeth, and for further observation applied better glasses than the former, the same gentlemen with myself agreed, from what we plainly saw, that the whole tooth was

made up of very small, strait, and transparent pipes. Six or seven hundred of these pipes put together, I judge, exceed not the thickness of one hair of a man's beard. In the teeth of a cow, the same pipes appear much bigger, and in those of a haddock somewhat less." Drawings of the teeth are given here, and also in his "*Continuatio Epistolarum*," which work contains the results of his researches on the teeth of the horse and the pig, which he likewise finds to consist of tubes proceeding from the cavity to the periphery. He here proves, too, that he was acquainted with the cortical substance, for, speaking of the teeth of the calf, he says, "*Undiquaque alio osse circumducti erant*;"—"*adeo ut jam me adhuc magis quam antea certum reddere possem, circum primo confectum dentem os accrevisse*," (p. 7.) He further speaks of crystals which he found in the cavities of the teeth of horses, and gives drawings of them. Strange to say, these statements attracted no attention either from his contemporaries or successors, though Portal, in his Histoire de l'Anatomie et de la Chirurgie (Paris, 1770, t. 3e p. 460,) cites the letter inserted in the Philosophical Transactions, observing: "Leeuwenhoek dit ici que les dents sont composées de très petits tuyaux transparents et droits, dont six ou sept cents égalent à peine un poil de la barbe," &c. In the "*Anatomia Plantarum*" of Malpighi, (Op. omn. Lugd. Batav. 1687,) the fibres of the enamel are mentioned and delineated. In his *Op. Posthum.* (Amstel. 1698, p. 71 et seq.) he calls it a "*substantia ossea filamentosa*," and a "*crusta candida filamentosa*." Speaking of the teeth of the calf, he says, "*interior* (substantia) *ossea est, et obscuram habet compositionem, quæ in piscibus tamen evidenter fibrosa est; in hominibus vero compacta valde. Ab hac exterius perpendiculariter erumpunt pili, ut in holoserico vil-*

loso, qui versus dentis apicem inclinari videntur." "*Hæ (striæ) intersecantur aliis quasi crassis lineis, brevibus pilis contextis, quæ eleganti ordine horizontaliter ductæ describi nequeunt.*"

Duverney is the author of a monograph on the teeth, which contains much more vague speculation, and much less solid research, than the writings on this subject by Leeuwenhoek and Malpighi. This author compares the membrane which surrounds the tooth to that which envelopes the fœtus, and calls it the "choroid." He says that the follicle has the form of the tooth which it is destined to produce; and thinks that the latter is composed of layers of which the most external are the hardest. According to him, the choroid abandons the tooth at the period of extrusion, and remains in the alveolus, of which it forms the periosteum.

Winslow (in his *Exposition Anatomique*, Paris, 1732, p. 46) says of the enamel, "This vitreous matter, or species of enamel, when viewed through the microscope, appears to be composed of a number of very short fibres, so arranged that at one extremity they point inwards, and at the other outwards." Ludwig, in his dissertation "*De Cortice Dentium*," treats particularly of the structure of the enamel, which he declares to be fibrous; he sets about indicating the direction of the fibres in the different parts of the crown, and says that they all leave an impress on the ivory.

Bertin, in his Treatise on Osteology, gives a complete description of the teeth, and states "that it has appeared to him that the layer of enamel which invests the crown

of the tooth is prolonged, notwithstanding all that has been said to the contrary, over the root, and that it only becomes weaker by degrees from the apex to the opposite extremity." (P. 242.) He says that the cavity of the tooth is not entirely empty; but is filled, on the contrary, by a soft substance, produced by a lymphatic juice, which becomes thickened, though still without acquiring the consistence of bone. "This," he continues, "is what I call the third substance of the tooth, differing from the kernel (*le noyau*) and the enamel," &c. He affirms, moreover, that this substance forms sometimes a hard mass, which has scarcely any adherence with the other two, but which at length is consolidated with the ivory.

In the "*Mémoires de l'Academie des Sciences*," there is a remarkable paper by Herissant on the formation of the enamel, and on the organisation of the gums. He admits that there are two species of gums, one temporary, the other permanent; the former being a tough tissue lining the whole extent of the alveolar arch, and closing up the alveoli; and thinks that when the tooth traverses it, it is exfoliated, as it were, and comes off in shreds. According to him, the sac that contains the dental follicle is a prolongation of the temporary gum; is the organ which secretes the enamel, and presents on its surface a great number of small vesicles filled with a fluid which, by a process of solidification, is converted into the latter. The views of Herissant are confirmed by Bourdet. Jourdain, in his Essays on the formation of the teeth, has described minutely the dental follicle from its first appearance till the period of birth; and he follows it in its successive evolutions. He describes also two canals in the lower jaw of the fœtus—one, which is only a furrow destined for the passage of the vessels and nerves of the

milk-teeth; the other, which is a true canal, transmitting those of the permanent teeth. These writings of Jourdain, which are devoted exclusively to the subject of the developement of the teeth, are of great interest; for it is evident that he made numerous experiments on the subject, and only describes what he saw.

JOHN HUNTER, in his work on the teeth, printed in London in the year 1778, describes with uncommon clearness and precision the results of the investigations which had hitherto been made on the subject; and adds an account of a number of important experiments made by himself. He says that the enamel, which he calls *lamina vitrea*, is composed of striæ running from the circumference to the centre; he believes that it is quite inorganic, because it cannot be converted, by any means whatever, into animal mucus: exposed to fire, it separates from the ivory. He calls the latter the osseous part of the teeth, and holds that it is analogous to bone. He says, however, that madder only reddens those layers which are formed whilst the animal is fed with it, and does not at all change the colour of those which previously existed,—a fact which shows that this substance differs a little from bone. A part of the tooth once impregnated with madder always retains the colour of the latter; and Hunter concludes from his experiments, that the teeth are to be considered as anomalous bodies with respect to their circulation.

He thinks that the roots are surrounded by a periosteum which comes from the alveolus, and which is prolonged into the cavity of the tooth; and that the ivory is formed of concentric laminæ. He states that the incisors have three centres of ossification; the canine only one, and the molars three or four: that the tooth, at the

moment of its extrusion, is a foreign body in relation to the gums; and that the enamel is probably secreted by the capsule which surrounds the body of the tooth before it is extruded. The milk-teeth he describes as being shed by a law of organising nature, and he denies that their removal is effected by the mechanical agency of their permanent successors. Such are his leading views—the results of his characteristic industry and accurate observation. On many points his work still continues a standard text-book. In every part of it he displays his usual originality; but still it is evident on perusing it, that the author did not enjoy daily opportunities for close observation on the subject, and that consequently he did not duly appreciate some points of great interest. Nevertheless, I have been informed, on authority which I cannot doubt, that when Mr. Hunter first came to London, his brother sent him to attend in the surgery of a dentist to give advice on any case which might present itself. His description of the anatomy of the jaws, and of the muscles which are connected with them, is given with his usual perspicuity. Very few of the appearances observable in health or disease seem to have escaped his penetration. He has left us many valuable hints to be worked out; and it is a reproach to subsequent inquirers that they have remained so long on record without illustration. His description of the swelling, which he calls *spina ventosa*, of the roots, and of the appearances of anchylosis; his apparently anomalous reasonings on the facts established by his beautiful experiments of feeding animals with madder—his observations also regarding the periosteum and the capsule, have always appeared to me to require accurate examination; nor can I help regarding as erroneous his views on the *necessity* for three fangs in the upper teeth of the human subject. His ideas

on the connexion of the gum and tooth are not fully worked out: this subject, with that of the functions of the cellular texture of the periosteum, is very interesting. It is singular to observe the manner in which our great physiologist expresses himself on points which he did not settle by actual demonstration; as, for instance, on the nature of the enamel, and on the mode in which the teeth are shed.

That he had no long and careful practice in the diseases of these organs is evident from some statements which would doubtless have been corrected, had he enjoyed better opportunities for observation. These statements have given rise to unwarrantable practice by superficial collators of information, whose respect for authority often leads them to follow it blindly without examination. I may instance here as prejudicially erroneous, his assertion that general affections of the system have less influence on the teeth than on any other part. On the subject of the wearing down of the teeth, he also makes a few remarks, which have led to very pernicious practice. He calls the extraction of teeth "a weakening cause," and says that "if by accident one tooth is lost, the rest will necessarily fail in some degree, even though they are sound, and likely to remain so, had not this accident happened; and this weakening cause is greater in proportion to the number that are lost. From this observation we see that the teeth support one another."

His practical remarks on the operations of stopping, extraction, &c., will not be assented to by the well-informed practitioner of the present day; yet they still frequently find a place in text-books, and are adopted by many as a guide in their daily practice. The art of transplanting teeth, which he illustrated by some very curious experiments, has been since adopted with very injurious

and even fatal consequences, but is now, I believe, almost entirely abandoned by all practitioners at home and abroad. A persuasion, however, seems still to linger in the minds of many, that there is a possibility of its being practised without any ill effects.—The indifference with which many practitioners still see dead teeth remaining in the mouths of their patients, as well as sundry unwarrantable measures, may be traced to doctrines promulgated by no less an authority than Hunter. But sixty years have now elapsed since he wrote, and the profession is surely justified in demanding a vast improvement in the acquirements of the practitioner who devotes himself to the care of these organs.

From the introduction to the pathological part of Mr. Hunter's work, the reader is led to conclude that a very low standard of education is necessary to fit the *officiers de santé*, on whom the management of these organs devolves, for the safe treatment of the diseases of the teeth, and the adjacent parts. He prefaces that portion of his work by stating, that " he purposely avoids entering into *common surgery*, not to lead the dentist beyond his depth, and to matters of which *it is to be supposed* he has not acquired a competent knowledge," and states, " that all the diseases of the teeth which are common to them with the other parts of the body, should be put under the management of the physician and surgeon; but those which are peculiar to the teeth and their connexions, belong properly to the dentist," and allows at the same time that " diseases in the teeth are apt to produce diseases in the neighbouring parts, frequently of serious consequences." That it is possible distinctly to comprehend the structure and diseases of any individual part without the general rudiments at least of a medical education, is a

position which is now generally rejected, and it is to be hoped with beneficial results. It is much to be regretted, moreover, that such talent as Hunter's should have so long sanctioned by its high authority many practices which, to the present day, are adhered to, and which tend to a direct increase of suffering, and in some cases even to the gradual destruction of life. His errors can only be explained by the limited field of observation and practice on these organs which he enjoyed ; a wider range of experience would soon have awakened his penetrating mind to a sense of the injurious nature of such practices, for instance, as " extracting a decayed tooth," in order to " boil and replace it," as applying the actual or other cautery to exposed nerves, where disease is present ; burning the ear with hot iron to cure the tooth-ache ; blistering for decayed teeth, &c. With regard to his directions for stopping, extraction, and other operations, it is very evident that he never performed these often himself, or his instructions would have been very different.

His general remarks on diseases of the teeth are replete with sound sense, and leave little to be desired. The practical observations on the cure of irregularity are good, but appear, in common with many other parts of the work, to be rather compilations from the practice of others than original observations. The principles laid down in the chapter on operations do not coincide with the notions of the present day, and it is astonishing that such a measure as transplanting and replacing teeth should have received his sanction, and have been the subject of repeated notice and elaborate investigation at his hands. Subsequent experience has added scarcely anything to the information on dentition contained in his chapter on thatsubject

His details on many of the essential points connected with the physiology of the teeth seem to have passed entirely undigested through a great proportion of the works on this subject, which have been published from his time to this.

In sketching the progress of surgical information in this particular department of science, we find a singular similarity between the opinions and even the diction of those two eminent writers, Ambrose Paré and John Hunter. Though the latter wrote no less than two hundred years after the former, science in this intervening period had made so little progress, that our great English physiologist seems to have had no more recent or better authority to refer to as a standard of facts than his antiquated French predecessor; a circumstance which marks well how stationary the healing art must have been during the seventeenth and the greater part of the eighteenth century.

The reader, doubtless, has already observed the similarity here alluded to; but as the subject is curious, it may be well to institute a more formal comparison. Paré, in the 36th chap. of his 10th book, in a passage quoted above, (p. 5,) recommends a hot iron, or cotton dipped in oil of vitriol to be applied in cases of tooth-ache, in order to " burn the nerve which is inserted into their roots." This does not much differ from Mr. Hunter's treatment, as we learn from the following passage: " The nerve may be burned; that this may have the desired effect, it must be done to the very point of the fang." Again, " Either of the concentrated acids, such as those of vitriol, nitre, or sea-salt, introduced as far as possible, is capable of destroying its soft parts, which most probably are the seat of pain." If the reader has any curiosity to trace further

the similarity between the surgery of these two writers, he may compare the whole of the 30th chap. of the 17th book of Paré with what Mr. Hunter says, from p. 17 to p. 20 of the second part of his work on the teeth.

In the 26th chap. of the 17th book of Ambrose Paré, we are told, amongst other things, that "if the teeth become loose by a fall or blow, they must not be taken forth, but restored and fastened to the next that remain firm, for in time they will be confirmed in their sockets, as I tried in Antonio de la Rue, the tailor, who had three of his teeth loosened, which were put in their places, and bound to the rest with a double waxed thread." He fed his patient with "broths, jellies, and the like, and made him astringint gargarisms," and "by these means brought it to pass, that he, a little while after, could chew as easily upon those teeth as upon the other." Mr. Hunter, after directing that sound teeth, extracted by mistake, should be replaced, desires similar measures to be adopted in accidents such as the above, and relates a case similar to the one narrated by Paré. It is curious that the very next paragraph in both these celebrated authors treats of the Transplanting of Teeth. Paré gives a case where this had been successful, communicated to him by "a credible person, concerning a lady of the prime nobility," whilst Hunter, I believe, is the only writer who has entered into the minute and circumstantial details of the practice.

In making a selection from the works on the teeth, which have appeared since what may be termed the present school of anatomy was founded, we cannot do better than begin with Bichat, with whom the course of modern improvement may be said to have commenced.

Bichat, in treating of the enamel, was unable to decide

whether it is an organised substance, or merely a fluid exuding from the external surface of the tooth, and hardening round it. His observations are more valuable where he comes to treat of the sympathies and functions of the teeth. After the eruption of the second teeth, he says that they evidently grow both longer and thicker; but that they lengthen only at the root; that the crown has always the same dimensions, and that its appearing longer in old than in young men is owing to the shrinking of the gums, which is also observed in persons who become emaciated, in those who have been under a course of mercury, &c. He adds, that the teeth only increase in substance internally, " the canal of the root and the cavity of the body become gradually narrower, and at length become obliterated: then, as the vessels and nerves no longer penetrate into the tooth, it dies and drops out of its socket; but this death seems to be also accelerated by the accumulation throughout its substance of phosphate of lime, which so predominates over its gelatine, that its vitality is entirely extinguished, so that, in this respect, the loss of the teeth presents a phenomenon similar to that of the falling off of the horns of herbivorous animals," &c. The ivory he considers to be of a rocky consistence, very different from cellular tissue. Its fibres, he says, are very close, run in different directions, but chiefly towards the root, and are distinguished with difficulty. He states that the internal cavity is lined with a thin membrane, " qui par sa face opposée revêt la pulpe."

The pulp he regards as a spongy substance, which appears to be formed by the interlacement of vessels and nerves; but the nature of which is not well known: its sensibility, however, he describes as great, and as equal at least to that of the marrow.

With regard to the phenomena of dentition, he asserts that, previous to the eruption of the teeth, the jaws of the fœtus seem to be of a uniform continuous texture; but when they are examined internally, the dental capsule is found to be a shut sac lining the alveolar cavity to which it adheres by prolongations. It leaves the alveolus where the vessels enter the pulp, and is reflected on the latter, forming an envelope for the vessels. In its general character he considers this membrane to be serous, as also from the manner in which it is reflected, and from the fluid which it secretes. Although the pulp and its vessels are covered by it, they are, he says, really without its proper cavity.

M. Blandin, the intelligent editor of Bichat's "General Anatomy," has published a very excellent treatise on the teeth, in which are incorporated his observations on these organs, appended to the last edition of Bichat. Contrary to the opinion of the latter, he holds that the teeth are not bone, but productions of mucous membrane, analogous to nails, hair, &c., and differing from bone in their external position, connexions, form, structure, developement, and uses. He considers that "the follicle of these *osteides*, after their eruption, bears a perfect analogy to that of a hair, and in fact is continuous near the neck with the common integument of the mouth, of which it ought to be regarded as a simple depression. Before the extrusion of the tooth this analogy exists positively, but is not very clear, and has been mistaken," he adds, "by Bichat, who represents the membrane proper to the follicle as forming a shut sac; whereas at present, and indeed since the work on this subject of M. Delabarre, it is acknowledged that the dental follicle is united at the gum to the

mucous membrane by a canular prolongation, which establishes a positive continuity on the one hand between the cavity of the mouth generally and that of the follicle, and on the other hand between the mucous membrane of the gum and the dental membrane. This canal, closed at an early stage by the approximation of its walls, but dilated at a later period by the tooth which traverses it for the purpose of arriving at the surface, represents in reality the neck of this particular follicle, but in a very elongated state."

Blandin states that "the dental follicle is composed of two divisions, viz. of the membrane which constitutes its parietes, and of the pulp or papilla on which the tooth is formed. The membrane of the follicle consists," he adds, "of two layers—of an external and fibrous one, intended to adhere at a subsequent period to the alveolus as the alveolo-dental periosteum, and which is *le derme* of the mucous membrane of the mouth depressed in the form of a follicle to a level with the teeth—the other layer is situated internally, is villous and vascular in its texture, and forms the cavity of the follicle. These two layers united are further described as extending to the base of the pulp, near the point at which it receives the vessels and nerves which form its pedicle; but neither the one nor the other is really reflected on the pulp, as Bichat supposed. This eminent physiologist was deceived on this point," says Blandin, "by the circumstance that the texture of the pulp is continuous with that of the internal layer of the follicle, from the bottom of which it is a vascular and nervous expansion—a papilla analogous to those found in all parts of the tegumentary membrane, (but more extensively developed on account of its peculiar functions,) and particularly to those of hair and feathers."

According to our author, the fluid of the follicular cavity differs in many respects from that of serous membranes, being more consistent and viscid, of a dark yellow colour, and possessing, moreover, peculiar properties, which Berzelius states to be owing to the presence of lactic acid.

Blandin considers that the relation between the dental papilla and the tooth is not analogous to that existing between primitive cartilage and bone; since the papilla does not ossify, any more than the papilla of a hair or a feather solidifies in order to produce those structures. He imagines that the tooth is secreted by the external surface of the papilla on which it rests; that it takes the exact form of the latter, and increases in length and thickness in the same way as hair, feathers, and nails—that is to say, by the successive addition of layers internally to those already secreted.

In regard to the production of the enamel, he allows that its origin is involved in great obscurity, and notices the conflicting opinions respecting it—Cuvier holding that it is produced by an immediate secretion from the internal layer of the follicle, whilst Hunter states that it remains for some time dissolved in the fluid of the follicle, and afterwards crystallises on the ivory of the tooth; and whilst others have held that it is also secreted by the pulp, and traverses the pores of the ivory in order to arrive at the surface. If any of these theories are adopted, it is difficult to explain why the root of the tooth, which, like the crown, is formed on the papilla in the cavity, and in the midst of the cavity of the follicle, should not be also covered with enamel. M. Delabarre has tried to solve this difficulty: he holds that the enamel is secreted by the internal layer of the follicle, but that this layer

does not descend further than the pedicle of the papilla—a theory which Blandin does not consider as satisfactory.

This author maintains that the yellow, calcareous matter, called tartar, is secreted by a series of small sacs which surround the mouth of the follicle.

In Great Britain, the principal works which have been published on the teeth during the present century are those of Dr. Blake, (8vo. Dublin, 1801,) of Mr. Fox, (4to. London, 1803,) and of Mr. Bell, (8vo. London, 1829.) And these I shall notice together, although not in chronological order.

The Essay of Dr. Blake must always be regarded as the best work on the subject of the period at which it was written, and will keep its place as a standard production. He is one of the few authors who have taken the trouble to read their lesson from nature; and the deductions which he has drawn from his observations are practically useful. His ideas respecting the "crusta petrosa" were original at the time, and have since been generally acquiesced in; but his views on most of the functions of the dental capsule are similar to those entertained by other writers, and very different from the opinions which I shall have an opportunity of stating in the course of the present work. His remarks on the succession of the teeth of fishes are very accurate.

We now come to speak of the justly celebrated work of Jos. Fox, which appeared in 1803. He was one of the first members of the profession who devoted his practical attention exclusively to this particular department of the healing art. As a practitioner he was most skil-

ful; and in his lectures at Guy's Hospital he laid much valuable information and many excellent rules of practice before the students of his time. The opinion he entertained of his great predecessor, Mr. Hunter, is thus expressed:—"Mr. Hunter's publication on the teeth was the first scientific book *ever* published upon this subject; and as an anatomical work must ever enjoy great celebrity; but *not having practically devoted much* of his attention to the operations upon the teeth, there can be no reflection upon Mr. Hunter's merit in stating, that in many essential points he was wholly but unavoidably deficient."* Again (at p. 18) he states that "into Mr. Hunter's treatise, for want of closer attention, many inaccuracies have been suffered to creep."

The developement of the teeth is very accurately described by this author, who, in his description of the successive appearance of the different teeth, anticipates the remark regarding the more early developement of the first small grinder, which more than twenty years afterwards was claimed as original by M. Serres. It ought to be observed, however, that from the cursory manner in which Fox mentions this fact, the subject hardly obtains its due importance. Serres, I have no doubt, was totally ignorant of the existence of Mr. Fox's work, or he must have known that the excellent plates in it present a correct delineation of this phenomenon.

Fox considers that the teeth differ in their formation from bones only in having a covering of enamel, and in being more dense, and he is a strenuous advocate of the vascularity of the teeth. He notices the intimate union of the capsule to the gums, and also the two layers of which the capsule is composed, both of which he states

* Preface, p. ix. Third Edit.

are vascular. He holds that the capsule or membranes derive vessels from the gums, but the pulp from the jaw. This is contrary to the opinions of Hunter and Blake, who again differ from each other, inasmuch as the former considers that the inner layer only is vascular, whilst the latter maintains that vessels are found in the outer layer alone. He mentions, (p. 23,) that in a young elephant dissected by Sir A. Cooper, " the adhesion of the pulp to the chamber around was strong, and required a considerable degree of force to separate." Cuvier expressly denies that any such intimacy of union exists in this case.

According to Fox, the enamel is fibrous, and the ivory stratified; he considers the periosteum of the fang common to both it and the alveolar process, and states (p. 2, Pt. ii.) that it is a reflection on the fang, being firmly attached to the gum at the neck of the tooth.

This writer again differs from Hunter in considering the teeth from their vascularity as similar to bone, and as only differing from it inasmuch as they are denser, and their exposed surface is covered with enamel. They are moreover subject, he says, to the same diseases as bone, but cannot exfoliate like the latter. In enumerating their diseases, he uses the same nomenclature as for those of bones.

According to him, it is a process of absorption which opens a passage for the extrusion of the teeth, this absorption taking place first in the membranes, and then in the gum.

Fox is at issue with Hunter on the subject of the origin of decay; the former expressing himself surprised that the latter should not have arrived at its true cause, which, according to him, is inflammation terminating in mortification. He considers that disease originally attacks the

internal membrane or pulp, causing suppuration, but not attended with decay in the solid substance of the tooth. In cases of this kind, he recommends a hole to be drilled in the side of the tooth to allow the escape of the matter. Under this head he observes, that the pulp in its diseased state is separated from the bone, (thus forming one of the causes of external decay,) but in its healthy state adheres firmly to it. As other causes of decay, he mentions the faulty organisation of the ivory or enamel, and many circumstances dependent on the constitution of the individual, as also contact with another decayed tooth, the crowded state of the teeth in general, want of cleanliness, disease of the gums, putrefaction from tartar, &c. His observations on the diseases of the teeth are excellent, and display much judgment and discrimination; but still an era of investigation has since commenced, which has thrown much new light upon the pathology of the teeth, and considerably facilitated the diagnoses of their diseases.

The remaining parts of Mr. Fox's work are replete with sound and valuable information. In the article on artificial teeth, he observes of Mr. Hunter's operation of transplanting, that " he was naturally partial to it from its being of his own invention." He is not, however, correct in this, as we have seen that Ambrose Paré alluded to it two hundred years before Hunter.

Fox's Operative Surgery was excellent for the time at which he wrote, but may now be said to be almost entirely obsolete.

The next work we have to examine is from the hand of that able and intelligent practitioner, Mr. Thomas Bell, the accomplished successor of Mr. Fox as lecturer on this subject at Guy's Hospital. In this

work are found incorporated all the facts known at the time, and many excellent practical considerations. He is of opinion that teeth are true bone. "That they possess vitality, and are connected by their organisation with the general system, having nerves, blood-vessels, and absorbents, and are analogous in this respect to true bone," is his expressed opinion.* He considers the membrane of the pulp to be a production of the periosteum of the alveolus. The adhesion existing between the membrane and the bone of the tooth he considers is owing to the passage of "numerous vessels, &c., from the one to the other;" and he shows throughout the whole of his work that he is a most strenuous advocate for a degree of vitality in the teeth equal to bone, and adduces as a proof of that opinion the red tinge in the teeth of persons who have died of strangulation. He considers that "the periosteum of the maxillary bones, after covering the alveolar processes, dips down into each alveolar cavity, the parietes of which it lines. From the bottom of the cavity where the vessels and nerve of the internal membrane enter, it appears to be reflected over the root of the tooth, which it entirely covers as far as the neck, at which part it becomes intimately connected with the gum."† The ivory of the tooth, he considers, is a secretion from the *membrane* of the pulp, and not from the pulp itself; and agrees with Dr. Blake in "*conjecturing* this membrane to be a propagation of the periosteum of the jaw." He agrees with Fox regarding the vascularity of both layers of the capsule, and that the external layer secretes the crusta petrosa. He divides the membranes of the teeth generally into deciduous and persistent; "the deciduous being the two lamellæ of the capsule; and

* Page 9. † Page 42.

the persistent are, 1st, the internal periosteum of the dental cavity ; 2nd, the periosteum of the root ; 3rd, the periosteum of the alveolus." He considers that the external layer of the capsule does not extend farther than the neck of the tooth, and with the internal layer becomes absorbed. The outer layer he considers merely rudimentary in man and other animals with simple teeth. The shedding of the temporary teeth he calls *a process of anticipation.* The practical digest of the diseases which occur both in the early and adult state of these organs is excellent, and conducts to the best rules of practice.

Since Mr. Bell's work made its appearance, we have had several manuals on the teeth displaying talent and industry, by Mr. Koeker, Mr. Jobson, Mr. Waite, and others.

To return to the French school.—In 1812 appeared the Baron Cuvier's work on fossil remains, every department of which displays equal brilliancy of talent. The section in which he treats of the structure of the teeth of the elephant, contains much matter of great importance. He holds that the ivory and enamel are formed by the gradual production of superimposed laminæ ; and, in direct opposition to the opinion of all his predecessors and contemporaries, he says, " *Pour moi, je me suis assuré que le cortical est produit par la même lame et par la même face qui a produit l'émail.*" He holds that the different substances which constitute the teeth are produced by excretion and in layers ; " that the internal substance in particular has nothing in common with ordinary bone but its chemical nature ;" that it consists of equal proportions of gelatine and of phosphate of lime ;

but that it does not resemble bone either in its tissue, or in its manner of deposition and increase. " *Son tissu*," he adds, " *n'offre ni cellulosité, ni fibres, mais seulement des lames emboitées les unes dans les autres.*" He gives at length his reasons for believing that it is entirely non-vascular.

In speaking of the capsule, he remarks, " *Il ne produit point d'émail ni de cortical sur les racines, parceque la lame interne de la capsule, qui a seule le pouvoir de secreter ces deux substances, ne s'étend pas jusque-la.*" (P. 43.) The recent researches of the German school decidedly prove this observation to be incorrect.

In treating of the tusks of the elephant, he states from actual observation, that there is no connexion whatever between the pulp and the ivory, and under this head he cites the appearance presented by the decomposition of fossil teeth as corroborative of his opinion regarding the concentric layers of growth.

His remarks on the diseases of the teeth are generally fraught with sound sense and practical information.

In 1817, M. Serres published a most interesting little work on the Anatomy and Physiology of the Teeth, in which he treats particularly of their organisation at an early stage. He says,* " The rudiments of the head, and of all the organs which it contains, exist almost as soon as the embryo begins to be distinct in the product of conception; the teeth, which are destined to perform the first function in the circle of life, are formed and developed in the interior of the maxillary bones. Preceding anatomists

* Essai sur l'Anatomie et la Physiologie des Dents, &c. Paris, 1817, p. 2.

have only ascertained the existence of their germs at a late period of fœtal life; but I have thought it necessary to examine them at as early a period as possible." "In the jaws of an embryo of two months, I found the germs of the first incisors and small molars; but I could not find the canine till two months and a half; at three months I discovered the germs, not only of the first, but also of the second dentition, and even that of the wise tooth. These germs are found lodged in membranous folds, which form at this period the gum; those of the first dentition are immediately attached to this fold; those of the second are suspended from it by a pedicle of about two lines long, which alone enables them to be distinguished, together with the yellow colour which they contract by exposure to the air, and which contrasts with the dull white of the gum. At four months I found fibrous partitions separating the incisors; but all the other germs were contiguous to each other. At six months the osseous partition of the incisors was very distinct; that of the small molar was also partly ossified; and the two posterior molars were contained in the same division."

He gives a very circumstantial account of the position of these germs, and of the mode of demonstrating them, which consists in detaching them from the internal portion of the alveolar arch. He comes to the conclusion that he has "demonstrated the presence of all the germs in the jaws of the fœtus." (P. 9.)

He states that he has insulated all the pulps of the first set in the jaws of a fœtus without disturbing either the capsule or the gums, and concludes that the pulp and the capsule "quoiqu' intimement unies sont distinctes l'une de l'autre." (P. 11.)

He then proceeds to describe the dental membrane, as he calls it, or capsule, enclosing the germs of the teeth, and in the interior of which these bones are developed. This he states to be composed of two plates or layers, "one external and the other internal, distinct not only in their destination, but also in their structure and functions. The external layer, which is fibrous, is opaque and whitish; on one side, it lines the interior of the alveolus, and serves as a periosteum; on the other, it is applied to the external surface of the internal layer. Closely adhering at its inferior part to the dental nerves and vessels, it unites with the cartilage of the gums, and when the tooth has protruded, *it embraces its neck.* It is endowed with a considerable degree of elasticity, and compresses the liquid in which the tooth is plunged: this appears," he says, "to be its use; for if a small opening is made in it, or if a small portion of it be removed, the internal layer, and the liquid which it contains, immediately protrude like a hernial sac through the opening, which proves that compression must be exercised by the external layer."

"The internal layer is a very delicate transparent membrane *sui generis.* Bichat affirms that it is serous; but it is entirely vascular, and differs in this respect from that class of membranes: moreover, the fluid which it secretes is mucous as well as serous. It differs from mucous membranes, inasmuch as it has no follicules, and in its natural position may be regarded as a closed sac. I consider it as intermediate between these two orders of membranes. Externally it is covered, as we have stated, by the external layer, to which it adheres with considerable tenacity, particularly superiorly at the place where it corresponds to the fibro-cartilage of the gums. At the spot

where the vessels and nerves penetrate, it detaches itself from the external layer, to which it does not henceforth seem to be united, except by means of small vessels which pass from one layer to the other. Being now isolated from the external layer, it is reflected from below upwards, and envelopes the vessels and nerves as far as the base and the inferior circumference of the pulp, where it is evidently inserted; whether it is continued over the surface of the pulp or not, I cannot say; but I have never been able to follow it further than the base, though I have made several careful attempts. It results from this arrangement, 1st, that the sac formed by this layer is closed above by the dental pulp, which forms a kind of lid to it; 2ndly, that this pulp is not enveloped by the membrane, and that it is free in the interior of the sac which it forms, bathed by the fluid which it secretes; 3rdly, also that the external membrane is prolonged no further than the place where the vessels and nerves pass in order to penetrate the dental germ, and that it closely adheres to them." (P. 14.)

Serres next proceeds to give an account of the dental arteries and nerves, and states that although the adult subject possesses only one canal, the fœtus, and even the infant till its sixth or seventh year, (or till that age when the removal of the first tooth commences,) possess two canals for the transmission of vessels: he gives a drawing of this arrangement, which I believe is far from having been established as a constant appearance.

"From whatever trunk," says this author, "are derived the vascular branches which penetrate the roots of the teeth, their distribution in the germs is always the same. When they reach the base of the tooth, they pierce the external layer of the membrane, and are continued to the

internal layer, on which they ramify to such an extent that this portion of it is rendered entirely vascular in appearance. Beyond the point where the internal layer of the membrane is inserted, several branches penetrate the substance of the dental bulb. I have followed them to the distance of a line from the point where dental ossification takes place. It is to be remarked, that all round the point of insertion of the internal layer into the base of the bulb, the vessels are much more numerous than at any other part, and that they form a vascular circle similar to the anterior and posterior circles of the iris; it is also to be remarked, that this circle, or this reddish areola, which they form on the bulb, descends in proportion as ossification advances, a circumstance which results from the mechanism of the formation of the teeth. It is worthy of notice and admiration, that these vessels, in teeth with a single root, form only a single bundle; in teeth with double roots, they form two bundles; and they are divided into three or four, if the tooth is to have three or four roots." (P. 19.)

In this work of Serres we find a minute account of the dental nerves, and of a plexus which, he says, is situated beneath the incisors and canines; and this is accompanied by some excellent remarks on the sympathetic pains experienced in the teeth and adjoining parts.

He is almost the first who pointed out what he calls the *dental glands*, which he describes as small sacs or cysts disposed in regular groups spread over the whole cartilaginous substance which forms the gums of the new-born infant. Their function, he considers, consists in lubricating the cartilages of the gums; they also, he thinks, assist the infant in the act of sucking, by retaining the nipple of the mother. He has succeeded in pressing a fluid like serum

out of them; and he says that they resemble the Meibomian glands. They are numerous, and the largest are situated on the internal portion of the gum. In the adult subject, Serres maintains that their function is changed to that of secreting the tartar; and he follows up this opinion by observations on that substance, which it is not necessary here to discuss. We must also pass over in silence his ideas on the physiology of the facial angle at the different periods of life.

The second part of his work is devoted to the physiology of the teeth; and he commences it by the general assertion that these organs belong to the osseous system, but are still of a different "*tissue*." They are composed, he says, of three different substances; viz. enamel which covers the crown, a bony part which constitutes the base, and a soft part which fills up the internal cavity, "*dont la nature ne nous est pas encore bien connue*." The position and texture of the enamel are well described. He considers that it does not acquire its hardness and polish till it is exposed to the air; and he combats the opinions of Herissant and Cuvier on this subject. He has never been able to see the follicles of Herissant. This substance has never appeared to him to be fibrous; and he asks why its functions are interrupted when it reaches the fang. After making observations and conjectures on the origin and structure of the enamel, he concludes by confessing that "*il reste beaucoup de choses à faire sur les dents*."

In regard to the osseous part of the tooth, or ivory as it is called, he commences by citing Bichat's opinion that it is fibrous, and dismisses the subject by observing that he has never been able to demonstrate any fibres in it, though he has treated it with acid, and submitted it to

the action of fire. He concludes by a series of observations (p. 45) on the difference which he considers to exist between bones and teeth, and these, in order better to illustrate the subject, we will place in parallel columns :—

A BONE	A TOOTH
Passes through a cartilaginous stage.	Passes through no cartilaginous stage, but is a *transudation* from the surface of the pulp.
Has a periosteum.	Has no periosteum.
Is affected by rachitis and the other diseases of the osseous system.	Is not affected by rachitis, or the other diseases of the bones.
Is destroyed by concentrated nitric acid.	Is *not affected* by concentrated nitric acid.
When calcined, leaves a white residue.	When calcined, leaves a bluish residue.
Is destroyed in extra-uterine conception.	Remains untouched in extra-uterine conception.
Is vascular.	Is not vascular.

Finally, bones decay much more quickly after interment than teeth ; and the diseases of bones and teeth offer the least possible analogy. Serres relates many curious facts touching the indestructibility of the latter.

The pulp he considers as especially formed by the nerve ; and in fact, he regards it as a " veritable ganglion," (p. 53.) ; and this opinion he follows up by speculations on its formative functions, and on the fluid which he says surrounds it.

He is opposed to instituting any analogy between the pulp and the cartilage of bone ; he regards the tooth as an evident secretion from the pulp ; and, with respect to the structure of the former, makes an unfortunate assertion which has been signally refuted by the researches of more recent inquirers in this branch of science. His

words are :—" A quelques epoques qu'on les considère, on n'aperçoit aucune trace fibreuse, aucune maille celluleuse, qui aient de la parité avec le système osseux." (p. 62.)

On the eruption of the teeth he makes some very excellent remarks ; but, together with all who have hitherto written on the subject, he holds that the capsule is absorbed, or detached from the crown, at the period of extrusion, but that it adheres to the neck, and forms by its external layer the periosteum of the socket, whilst its internal layer adheres to the fang of the tooth.

With regard to the order of eruption, he is one of the first who pointed out a circumstance of considerable practical importance, which is, that the first small grinder succeeds next to the lateral incisor, and that the canine appears afterwards, contrary to the generally received opinion that the canine succeeds the lateral incisor ; he gives a summary of reasons why the former must be the case.

His views on the process of shedding, and on the various theories extant on this subject, are concisely stated ; but it does not appear to me that his own hypothesis throws much new light on this process. His explanation resolves itself to the acknowledgment of a " loi primordiale, dont on ne peut donner aucune raison physique," which destroys the partition between the alveoli of the two sets of teeth, and liberates the root of the first tooth, which becomes loose, and falls out on the slightest movement. He does not consider it as a necessary consequence that the fangs of the first set should be absorbed.

He discusses at considerable length the order and period of appearance of the second set of teeth, and the contradictory accounts which have been given of this phenomenon ; he has evidently studied the subject, and his own ideas on it are narrated with great perspicuity.

He concludes his work by a rather lengthy enumeration of supposed examples of third sets of teeth, and of other irregularities.

Generally speaking, his pathological remarks, such as those respecting stumps, do not accord with the results of practical observation.

The genius of Baron Cuvier not only displayed itself in his own discoveries, but in the facilities which it opened to the researches of others. Two works on the teeth have originated with his scholars, both of which confer great honour on their authors. The first of these appeared in 1825, and is entitled, "*On the Teeth of the Mammalia considered as Zoological Characters*," by F. Cuvier: a work forming a most useful and interesting accession to our knowledge of natural history. The illustrations are executed with great care and fidelity, and form a perfect text-book of reference. The work is preceded by a most valuable dissertation on the developement and structure of the teeth, replete with sound sense and accurate observation. The author considers the teeth as appendages to the skin, and as analogous in some respects to the other dermal appendages, inasmuch as they are secreted by somewhat similar organs; and also, inasmuch as they may be said to be dead, being devoid of vessels and nerves, and consequently insensible. But, though they resemble dermal productions in these respects, he does not think that they ought to be included in the same category, seeing that they still differ from them in some essential particulars. According to him, the Ornithorynchus possesses the most simple teeth, for in this animal they are entirely composed of gelatine. The next in order have a gelatinous base with earthy salts deposited in their meshes. These two forms, simple

as they are, differ essentially from horn or hair; and he considers them as true secretions from organs destined for the purpose. In common with his brother, he regards them as distinct from bone; but at the same time he admits that they are more similar to the latter than to either hair or horn.

To whatever set of appendages they may be considered as analogous, the teeth, he says, consist of a secreting and a secreted portion, at their origin as well as during their whole life. The secreting organ, composed essentially of vessels and nerves, is always placed internally, and is composed of three, or at least two, other organs. Around this is deposited the secreted portion, formed of a certain number of substances entirely non-vascular, and removed from all immediate connexion with the system at large. It can be demonstrated, he continues, by mechanical analysis, that only three substances enter into the composition of all the different classes of teeth. One class consists of ivory, enamel, and "cortical;" a second, of ivory and enamel; a third, of ivory and cortical; a fourth, of ivory alone. The two kinds of fangs he designates as real and apparent.

His views on the capsule are as follows:—"It appears to be a production of the maxillary nerves and vessels; but it is not without relation to the contiguous parts, being even connected with the gum, but to a much less extent than most authors have stated." He calls this a secondary attachment, but has not had an opportunity of examining it at an early stage of developement. The capsule, he states, is adapted to the nature of the tooth which is to be formed from it. Thus teeth which are composed of three substances, have capsules divided into three distinct portions, each of which is to be considered

a distinct organ. The first of these is the central portion or bulb, which produces the ivory; the second is in the form of a membrane, and produces the enamel; the third, called by our author the external, envelopes all the others, and produces the cortical or external ivory.

The bulb, he says, appears to be entirely composed of nerves and vessels, and is surrounded by the "membrane emaillante," except at its base, corresponding to the neck of the tooth where the membrane terminates. It is deprived of vessels and disappears entirely when the functions of the external membrane commence. The external membrane he describes as highly vascular, and as forming an external pulp: he assigns to it the formation of the cortical substance, and the protection of all the other formative processes of dentition. "*Elle est percée*," he adds, "*à son sommet par l'évolution de la dent, mais ses bords s'attachent aux gencives, et en deviennent en quelque sorte la continuation.*" (P. xxiv.)

In the tusks of the elephant, he considers that the ivory is deposited in concentric layers, and refers for proof of this to fossil remains: its texture differs, however, in different animals—in man, the monkey, and in carnivorous animals, for instance, it appears to be fibrous. It is of a uniform contexture in the whale, hippopotamus, &c., whilst the teeth of the oryctcropus seem formed of longitudinal and parallel fibres, "*qui rappellent la structure du jonc.*"

The enamel F. Cuvier describes as apparently crystalline, and as deposited in a direction contrary to that of the ivory. According to him, the cortical substance is of "absolutely the same" nature as the ivory—generally speaking, it contains only gelatine and phosphate of lime; but in some cases colouring matter in addition, as for

instance in many ruminants, in the incisors of the castor, hedgehog, &c.

He relates that, amongst herbivorous animals, the vitality of the pulp continues for several years, but ceases in carnivorous animals at a very early period.

The two sections which this writer devotes to the consideration of the relative developement of the teeth are admirable, and contain a mass of excellent and original matter.

The second work by a scholar of Cuvier, to which we have above alluded, is the "*Comparative Anatomy of the Dental System in Man, and the principal Animals. Paris,* 1827. *By* M. Rousseau." This author acknowledges that the subject is part of the "Baron's great domain;" but he has cultivated it with great industry, and has arrived at some very interesting results. His description of the anatomy of the jaws and gums is quite satisfactory as far as it goes; but he concludes the subject by saying, "*Il me semble que ce point d'anatomie n'a pas été jusqu' ici aussi bien éclairci qu'il est susceptible de l'être.*" (P. 45.)

At the commencement of his general considerations on the developement of the teeth in man, he remarks, "that it is probable that the embryo contains, from the first moment of its conception, the rudiments of all the organs ultimately necessary to the existence and perfection of the individual." He gives a very excellent description of the sacs and pulps, agreeing with Herissant in his views concerning their anatomical structure and functions. He believes that the formation of the ivory does not commence until after the enamel has began to be deposited.

Mr. Hunter's experiment with madder proves, he thinks, the concentric deposition of the dental substance; but, strange to say, he ascribes that experiment to Cuvier, whose work was not published less than forty years after Mr. Hunter had described it. With respect to the fibrous structure of the teeth, he compares its appearance to the rays of a quill. He notices and explains the "*osteides*," which are found occasionally in the internal cavity of the teeth, and which Bertin had noticed before him.

According to Rousseau the second set of teeth are more solid than the first, being required for harder aliment. He asserts that the first set of teeth exert so strong a pressure on the alveolus, that they deprive the milk-teeth of nourishment and vitality by compressing the nerves and vessels which are distributed to them. In his opinion the order of succession is quite different from that which Serres gives with regard to the canine.

The work under consideration gives a very accurate description of dentition in many of the lower animals. The porous appearance of the teeth of the orycteropus is remarked, which has so erroneously been considered as a striking example of the tubular structure of the teeth.

Rousseau maintains that what has obtained the name of cortical or cement, is nothing but a *dental tartar*, and he attempts to explain the manner in which this is produced.

The section which he devotes to the "aberrations and maladies of the dental system," is very instructive. He traces the origin of the erosion of the teeth to a congenital source, and explains the mode in which he conceives that it is effected. "There are examples," he says, "where the fœtus has been attacked by partial or general inflammations, without any morbid affection on the part of the mother . . . . This truth has been confirmed by the exa-

mination of subjects, in whom some teeth of the first dentition were apparent, on the enamel of which were observed points similar to those produced by engraving or chiseling; which proves that these inflammations having attacked a greater or less quantity of the small vesicles which secrete the enamel, at the moment when nature was engaged in the formation of the dental system, deprived of this substance all the places where they caused ulceration and the destruction of these excretory glands, leaving there furrows, which are called *erosions*." (page 240.)

In regard to the accidents which the teeth experience, he attaches considerable importance to the cracking of the enamel by rapid alternations of heat and cold, and cites an old adage, "that a glass of wine drunk immediately after soup draws a crown from the pocket of the physician, and puts it into that of the dentist."

Caries of the teeth, according to this author, is simply ulceration—many causes, both internal and external, predispose to this malady, as a scrofulous or scorbutic diathesis, the humidity or particular character of the atmosphere, the nature of the water which is drunk, &c. &c. The latter causes are supposed to operate in the province of Caux in France, and in the neighbourhood of Beauvais in Picardy, where the greater part of the inhabitants have the two centre incisors of the upper jaw decayed: after these the laterals begin to be affected, and so on, so that by the time the individual has arrived at the age of thirty, he has in general lost almost all his teeth. Rousseau is unable to decide whether this results from the air, the water, or from the immense quantity of apples which are consumed in these parts. He remarks, "that the inhabitants of large cities are most subject to decay of the

teeth—that the dog, the faithful companion of man, in good or bad fortune, is often attacked by it, and that the cat, which inhabits our houses, is equally liable to it." Savage tribes, on the contrary, appear to retain their teeth in health, although worn.

Carnivorous animals have very healthy teeth: in the savage state, indeed, time appears to effect no change in them, except that by degrees they become worn down.

Amongst other cases of disease in the teeth, Rousseau mentions one of a bony growth internally, and another of exostosis of the fang, similar in structure to the latter.

In the excellent edition of Hildebrand's "*Handbuch der Anatomie*," by Weber, we find the following on the structure of the ivory: "Although its fracture in recent teeth is smooth, and shows no fibres or leaves, still many facts prove that its substance is not quite uniform. The fractured surface has a bright silky lustre, which is still more perceptible when it is polished. In teeth which have been fractured longitudinally, bright lines are seen, curved in much the same manner as is the inner surface of the cavity of the tooth on the side which is towards the surface; whence we may presume that the osseous substance of the tooth consists of several concentric layers, which we have no method of separating from each other. Teeth are also more easily broken longitudinally than in any other direction; and Rudolphi observed that when the osseous substance of the crown was separated in very diluted nitric acid from its investment of enamel, the crown (but not the roots) divides longitudinally into several pieces, of which the number is tolerably definite in the different classes of human teeth. In Weber's edition of Rosenmüller's "*Handbuch der Anato-*

mie," fifth edition, Leipsic, 1833, it is stated that the ivory, macerated in diluted muriatic acid, is converted into a white, half-transparent, smooth, shining cartilage, in which no fibres can be distinguished.

The discovery of the lines or streaks above alluded to has been attributed to Schreger, but this is a mistake, they were mentioned by Duverney so early as 1639, and have been distinctly described by Sömmering. In Cuvier's "*Recherches sur les Ossemens Fossiles,*" (t. i. p. 31,) he thus speaks of the structure of the ivory in the teeth of the elephant: "Its tissue is neither cellular nor fibrous, but presents merely laminæ encased one within another." Wagner says of the ivory, that it presents "a hard, shining, sometimes foliated or fibrous arrangement." (*Verg. Anat.* Leipsic, 1834, 1835.) Frederick Cuvier says, "that the teeth of man, of monkeys, and of carnivorous animals, have an ivory of a silky appearance, which seems formed of fibres." (*Dents des Mammifères. Discours Prelim.* p. 27). G. Cuvier describes the enamel as follows—(*Sur les Ossemens Fossiles,* tom. I. p. 34)—"In the first place, the enamel is deposited on the surface of the substance called osseous by the internal membrane of the capsule, in the form of little fibres, or rather of little crystals, all perpendicular to this surface, and forming there at first a sort of velvet *à brins fins.* When the capsule of the germ of a tooth is opened, the little molecules of the future enamel are found adhering, but as yet very slightly, to the internal face of this capsule, and are easily detached from it. A part of them are even found swimming in the liquor interposed between the capsule and the germ."

The "crusta petrosa" has been seldom mentioned by

writers on the teeth. Hunter only speaks of it in the first stage of its formation. Tenon, in his excellent Treatise on the Changes of Form in the Teeth of Horses, (Mem. de l'Institut National. des Sc. et des Arts, sec. Math. et Phys. pour l'An. 6, p. 568,) is the first who gives a good idea of it; he calls it *cortical osseux.* Cuvier (op. cit., p. 35) says, " that the 'cortical' is produced by the same lamina and the same face which has produced the enamel; which is proved by this lamina remaining externally to the 'cortical,' as it was before external to the enamel, and that it is soft and loose so long as room is left it by the 'cortical.' The nature of its tissue, however, changes: so long as it only furnished enamel, it was thin and transparent; but in order to produce the 'cortical' it becomes thick, spongy, opaque, and of a reddish colour."

In tracing the progress of knowledge in this department of science, we have now arrived at an era of novel and important investigation, highly honourable to the zealous inquirers who have commenced it, though more from the results it promises than from the practical facts which it has as yet established.

Researches on the structure of the teeth by Purkinje have lately been given to the world in a dissertation by one of his pupils, (*V. Fraenkel de penitiori dentium humanorum structura observationes.*) Purkinje found in the gum of the new-born child the small sacs discovered by Serres, and, in the fluid they contained, thin quintangular lamellæ enclosing in their centre a round kernel, which he also found in the saliva and epithelium. He states that the substance of the tooth and the enamel have a near similarity to the structure of bone,

but on the outer surface of the root, he says, that there is a layer of true osseous substance, in which, at any rate, may be seen the osseous corpuscula which he has discovered.* This same structure he has discovered in the cement of the teeth of several animals. The proper dental substance examined in thin polished lamellæ consists of a uniform structureless (*structurlos*) substance, and of fibres passing through it. These latter run in parallel lines from the outer to the inner surface of the tooth, obliquely in some places, straight in others: they are in every part nearly of the same size, and communicate by but few branches with each other. Though they are very thickly placed, still the structureless intermediate substance forms the greater part of the mass of the tooth: as their diameter he gives one-fifth or one-sixth of the space between two of them. He has also discovered that these fibres are tubular, and that in the teeth of the horse, at any rate, they are capable of absorbing ink by capillary attraction—a fact which is also confirmed by Müller. As to what these tubuli may contain in their normal state, Purkinje is silent; but Müller has instituted researches which go to prove that parts of them, at any rate, are filled with inorganic, calcareous salts. The latter goes on to say, that when the light falls on fine polished lamellæ of dental bone, the white colour of the tooth is soon seen to be owing to these tubes or fibres, and that the intermediate substance is more transparent; moreover, that when such sections are submitted to the action of an acid, the white colour of the fibres disappears, the remaining cartilage still presenting tubes in their interior, which, however, when dried, are no longer white. He saw in healthy as well as in carious

* Müller states that he has had frequent opportunities of confirming these results.

teeth, that in parts of these tubes something was contained. Linderer, who has long been engaged in researches on healthy and decayed teeth, has observed, that the dental substance in the latter (even where the enamel only is affected) loses its colour in several parts between the carious spot and the internal cavity. As this is nearly always the case, it is evident that an alteration in the substance of the tooth must be produced by the superficial caries. In fine polished sections of such teeth, Müller could easily see with the microscope, that where they were become transparent, a crumbly substance was contained in parts of the tubuli, and that this substance was more coherent in the tubuli of the white tracts; by adding diluted acid, he also observed under the microscope that this crumbly substance was dissolved. He has often performed this experiment with the same result on fine polished slices of healthy teeth. In these he found individual fibres, frequently in considerable number, on which were dark spots following close on each other.

Inasmuch as the dental fibres have their white colour destroyed by acids, whilst the intermediate substance remains transparent, it follows that either the parietes of the tubes, or their interior, must contain calcareous salts. In breaking fine sections of teeth perpendicularly to the fibres, Müller has frequently seen the latter projecting a little at the fractured edge. In such cases they are quite straight and not curved, and seem to be not at all flexible. Hence it follows that the tubes have an organised basis, a membrane, and that this in the solid tooth is stiff and brittle, and probably saturated with calcareous salts, but weak and soft in the tooth which has been deprived of the latter.

The calcareous salts of the tooth exist not merely in the

tubuli, but also in the intermediate substance, which contains, at all events, the greater part of the calcareous earth, either chemically united with the cartilage, or deposited in it in an invisible manner. The calcareous earth of the intermediate substance may be rendered visible, by carefully boiling for several hours fine sections of teeth in a solution of potash. The substance between the fibres, which was before transparent, then becomes, from the solution of a great part of its cartilage, opaque and white; and the sections are rendered extremely brittle, and cannot without great caution be further polished. The calcareous matter presents the appearance of thick-set granules. Near the cavity of some teeth which had been treated in this way, lines were observed running parallel to the surface of the former.

According to Purkinje's researches the enamel consists of simple perpendicularly-placed fibres, increasing somewhat in size towards their upper extremity, forming quadrilateral prisms, and often making several curves on one and the same level. These fibres are adherent to lamellæ, which run transversely round the tooth, and generally rest obliquely on the surface of the dental substance. These observations are fully confirmed by Müller, who has examined the last molar tooth of a calf, on which the enamel was still soft, and found that even in this state the latter consists of separate prisms, as yet uncemented, but held together by a transparent fluid matter. These firm but somewhat flexible fibres are not easily acted on by acetic acid, but quickly dissolve in muriatic acid, without any perceptible escape of air.

The interior of the roots of old teeth consists, according to Purkinje, not of dental substance, but of bone properly so called, as does also the deposit on the external surface

of the root, and this statement is confirmed by Müller. The teeth have been reckoned by some amongst the corneous formations; but though they grow in layers like the latter, still they contain no horn, as Müller has repeatedly satisfied himself, but true cartilage yielding glue. From the dental cartilage of a horse's tooth, he obtained by boiling a large quantity of beautiful colourless glue. Whalebone, and other corneous formations, which supply the place of teeth, consist, he has found, of true horn, and furnish no glue, however long they may be boiled. It would seem from this, that horn supplies the place of dental cartilage when the teeth contain no deposition of calcareous earth. This is the case, at any rate, with the vertebrata.

We now proceed to give an account of the late researches of Professor Retzius,* of Stockholm, which have excited so much attention, and thrown so much light on the structure of the teeth. He first examined the cartilage in teeth which had been macerated in diluted muriatic acid, and found, on making sections of it, that it appeared to consist of slightly undulating fibres lying close together, resting with one extremity against the cavity of the pulp, whilst the other terminated near the surface of the tooth. It was not till a subsequent period, he says, that he discovered that these were hollow; but in the meantime he observed no internal similarity between this cartilage and that of bone. He next procured, with the aid of a file, slices of tooth-bone as thin as writing-paper; increased their transparency by means of olive-oil and turpen-

* The title of the work of Retzius is quoted above (p. 1): an excellent account of his discoveries was also published in Müller's Archives, in 1837 and to this I have been greatly indebted in drawing up the following sketch.

tine varnish; and on examining them under the microscope, found that they were composed, not merely of hollow fibres, but of ramifying tubes, of which the trunks open into the cavity of the tooth, supporting themselves on its pulp, whilst their terminations, in the form of extremely fine branches, run towards the external surface of the tooth. The branches were most distinct, and most easily shown at the external extremities of the main tubes; but in the whole course of the canals, both dichotomous divisions and delicate branches were observed; the latter were infinitely minute, and formed, as it were, a peculiar vascular system. Under reflected light, and on a dark ground, all these tubes seemed to contain a white matter. The enamel he found to consist of hexagonal solid prisms,* on which were generally observed transverse lines or streaks, making them appear as if they were formed of several pieces, lying one above the other: they rested with one end against the crown of the tooth, and with the other formed a part of its surface. Round the roots and necks of teeth he found a structure presenting some similarity to osseous substance, from the small cavities it contained, which, under reflected light, appeared to be filled with white matter, and from the number of winding, anastomosing tubes, as well as other larger canals opening into these cavities. This is the cortical substance which has been described as existing in the teeth of elephants, pigs, and oxen, by Tenon, G. Cuvier, and Fr. Cuvier, but which plainly forms part also of the teeth of man, and many other animals, in which it has not hitherto been remarked.†

In man the contiguous tubes appear to run parallel to

* Plate A. 1. Fig. 1. † Plate A. 1. Fig. 2. a. a.

each other; * but when several distant ones are compared, they are found to radiate, as it were, from the cavity of the tooth. In a few parts only of the fully-developed tooth, and not constantly even in these parts, do the tubes proceed directly from the cavitas pulpæ to the external surface: these parts are those which correspond to the apex or apices in the crown,† and to the commencement of the inferior third of the root. In the other parts, most of the tubes assume more or less the form of a line with three curvatures, frequently resembling the Greek zeta. The central curvature points inferiorly or internally; the outer extremities of the tubes turn inwards towards the axis of the tooth, or towards its surface. Where the tubes are the shortest, which is the case near the end of the root, the central curve only is seen, and it is convex towards the surface. Sometimes a fourth curvature is observed, which has of course the same direction as the second; but he only found it at the inner extremity of the tubes, where these were last formed or prolonged, in order to close gradually the cavity of the pulp. In some cases, towards the root, two curvatures are found; the tube having then the form of an *ſ*: the external one then points towards the root; still, by means of the microscope, another small curvature in the opposite direction is generally found at the extreme end, which is neither perceptible to the naked eye, nor by means of a ' loupe.' The curvatures on both sides appear, in well-formed teeth, to present a certain symmetry, so that the cavities on one side correspond to those on the other, &c. Hence towards the middle of the crown, the central curvatures come to diverge, and those which point from within outwards to converge. The curvatures are found to be most regular in sections of the front teeth, cut

* Plate A. I. Fig. 2. b. † Plate A. I. Fig. 2. c.

from before backwards, and parallel to the axis of the tooth. They are less regular in the side teeth, which have several apices, and particularly in that part of them, which in the crown forms the wall of the cavity of the pulp; also in that side of the root which in thin preparations is shown to be a continuation of this wall, lying close to the longitudinal axis of the tooth: finally, they are less regular at the extremity of the roots. In a perpendicular section of the front teeth from right to left, or from left to right, most of the tubes in the crown are seen to approach a perpendicular direction, and they are generally straight. As Leeuwenhoek, and also Purkinje and Fraenkel have remarked, the most internal tubes in the crown are generally perpendicular; those on the sides of the crown, more oblique; and those further down towards the root, more transverse: in some roots, the lowest of all are again oblique. Besides the larger curves, the tubes, when more highly magnified, present an immense number of other short curvatures, of which Retzius says he has counted so many as two hundred in the extent of a line. These curvatures, however, are very various in different teeth. In the milk-teeth they are generally fewer in number, and more lengthy; they are also fainter towards the outer extremities of the tubes than at their centres. Besides these are seen, particularly in old teeth, other curvatures more or less deep, which in a number of contiguous tubes correspond to each other; and it is these nearly parallel flexions which principally form the concentric lines, running nearly parallel with the inner surface of the tooth, and of which Leeuwenhoek remarked, that they could not be produced by tubes running in a longitudinal direction.

When the tooth is being formed, the outer extremities of the tubes are first developed; these grow inwards of course,

and become joined with that part which is subsequently produced, and a continuous canal is at length completed. This process would seem to be effected in stages, in each of which one curvature is added to the preceding ones; and hence we may conclude, that a certain undulating motion takes place on the surface of the pulp during the deposition of the dental bone.

In general, and particularly in the teeth of old persons, it seems at first as if these tubes did not divide or give off branches; they seem too, under the microscope, to be of the same diameter in nearly their whole extent; but this is not the case in reality: they all divide and give off branches, and their diameter diminishes towards their outer extremities in every case. From their commencement at the cavitas pulpæ, for five-sixths of their course, they appear to be of the same diameter in fully-developed teeth; and this diameter Retzius, with the aid of one of Frauenhof's micrometers, has ascertained to be $\frac{1}{417}$ Paris line, or about $\frac{1}{383}$ of an English line. In their remaining course their diameter diminishes considerably, until they, as it were, disappear, or terminate in small, irregularly circular, scattered cells. The distance between the tubes at their middle equals about the breadth of three of them; but at their commencement at the cavitas pulpæ, they are nearer than this to each other. When very thin and transparent slices are examined on a clear day under a glass of 300-500 times magnifying power, it is found that these canals are main tubes, dividing dichotomically, and giving off in their entire course an infinite number of smaller subdividing branches, which partly help to fill up the spaces between the tubes, and partly cross over the latter, and are lost beyond them. These branches are almost always easily perceptible in the milk-teeth.

In the permanent teeth the branches are found almost

without exception at the outer extremities of the main tubes: those which are given off more internally are fewer in number, and often appear as nothing more than roughnesses or points on the tubes in the crown and neck of the tooth. On the other hand, they are very easily seen in the most recent, and as it appears more imperfect formations of the tooth, as, for instance, in the wall of the crown, which looks down towards the bottom of the alveolus, which in the side teeth of the lower jaw is beneath, and in the side teeth of the upper jaw above, the coronal portion of the cavitas pulpæ (*superficies alveolaris* of Fränkel;) as also in the roots of the side teeth with more than one apex; and, best of all, in that part of the root which, within the cavity of the pulp, lies towards the longitudinal axis of the tooth. Retzius could not discover that the branches from different tubes communicated with each other, except, perhaps, at their extremities.

Most of the preparations which Retzius examined had been moistened with water, or soaked in olive-oil, or turpentine varnish: without which, he considered, they would not have been sufficiently clear. He found, however, that if completely penetrated by fluid, they became too transparent; the tubes and their branches filled up, disappeared, and left merely indistinct, delicate, faint streaks behind. The most delicate branches are first penetrated, and so are the first to vanish, leaving only here and there a curved line. On the other hand, when a preparation, either of a recent or dried tooth, newly-made and fresh dipped into one of the above fluids, is examined, the branches are seen in all their delicacy and abundance. But in proportion as the water, oil, or varnish penetrates them, they fill and disappear. From the same cause the main tubes in some parts of different preparations of teeth,

particularly of their roots, are found to have disappeared entirely in some places, and to have broken off, as it were, and have run into the faint lines above mentioned in others. Hence also teeth which have been long immersed in spirits of wine become quite transparent and similar to horn, like dried teeth which have been long kept in oil.

When the wall of the cavitas pulpæ is viewed under a glass of a sufficiently magnifying power, it is found to be perforated like a sieve, and to present an immense number of orifices, which are the mouths of the main tubes. When a section of tooth-bone is made transversely to the latter, which is most easily effected in the crown where the tubes run parallel to the axis of the tooth, their interior is rendered visible. They appear like rings, and are dark or light, or partially light, according as the light falls into them. Under a certain light they are bordered by a definite shadow, and when the light falls directly into them, present an appearance different from that of the substance of the tooth which surrounds them. Frequently these rings are of a darkish colour verging towards yellow. From these appearances Retzius confidently concludes, that the tubes are not merely hollowed out of the substance of the tooth, but that they are true canals having their own walls; that the latter are of a structure differing in appearance from that of the tooth; and that the round spot inside the ring is the opening of the canal. When the transversely-cut preparations are viewed on a dark ground, the round circular spot is seen to be white; and white spots only are visible where before there were generally transparent tubular orifices. Retzius was not able to see the rings or the walls of the tubes when he viewed the preparations on a dark ground.

With respect to the contents of the canals, he found

with Professor Müller that they consisted of an inorganic or earthy substance, which, when seen on a dark ground, seems white, and which disappears when the preparation is submitted to the action of diluted muriatic acid. When the light falls into the canals, this matter is seen to be composed apparently of infinitely fine particles, adhering together in lumps. The greater or less number and distinctness of these lumps seem to depend on the degree in which the preparation has been penetrated by water, oil, or turpentine.

The *Enamel*, according to Berzelius, " after its solution in acids, leaves no cartilage, but only an extremely slight, brown, membranous tissue, which had adhered to its inner surface. On being submitted to fire, it is not at all blackened externally, and but very little internally; has a slight ammoniacal odour; and it loses, after having been well dried, less than two per cent. of its weight by burning. Hence we see that it essentially contains no ammoniacal matter." After quoting this passage, Retzius states that the enamel is adherent internally to a thin membrane, which, he continues, is probably the remains of that surrounding the organ for the production of the enamel, which has been described in such a masterly manner by Purkinje. This membrane resists, for a long time, the action of water. In teeth which had been macerated for several months in water, he has found it remaining on his separating and dissolving the enamel in acids. To his great astonishment, when he once dissolved in diluted muriatic acid a large slice of enamel from the fossil tooth of a horse, (which had been dug out of a turf-moor,) he found, after the solution had been effected, this membrane floating at the top of the fluid. He examined it under a glass of considerable magnifying power, and found it

perforated in every part, but it showed no traee of fibres.

In the fossil teeth of this horse, Retzius had an opportunity of observing the different degrees of durability of the different parts of the tooth. The cortical substance of the external side of the teeth had fallen off altogether : in the recesses its texture was so loose that it crumbled away as soon as it was touched. The dental bone was also, for the most part, destroyed : that which remained was very friable, and resembled brown velvet. It was separated, as it were, into fibres of a loose texture, which ran in the same directions as the tubes. The greatest part of the residue of the tooth eonsisted consequently of the enamel, and this had the same crystalline appearance, and the same hardness as in a dried, recent tooth. This faet again tends to prove that the enamel is very slightly organised, and that it contains very little organic matter. When very recent, however, it seems to present an exception to this rule ; for if the loose enamel, which has as yet only attained a slight degree of consistence, be separated from the tooth whilst the latter is still in its sac, or, better still, from the root of a young horse-tooth, it can be easily dissolved, and falls partly into irregular pieces, and partly into extremely delieate prisms.

When recently-formed enamel is submitted to the action of diluted muriatic acid, every delicate prism leaves behind on itssolution a small portion of organic matter : but as this cannot be found at a later period, it is probably only a deposit from the moisture, which in the first place surrounded the enamel fibres. These latter are still invested by this organic deposit when they are first arranged together ; but as they become closer pressed, and new ones are wedged in between them to form the hard enamel of

the adult tooth, this deposit, Retzius imagines, is, as it were, dislodged, or pushed away, or remains in such a small proportion that it cannot be recognised in an isolated state.

The enamel-fibres appéar under the microscope as small angular needles, about one-five-hundredth of a line P. M. in diameter. On many of them are small, crowded, transverse streaks, of which some run round the entire fibre, some round only a part of it. The fibres are seen in connexion with each other when thin slices of enamel cut longitudinally through the cavitas pulpæ, and near its central line, are examined under the microscope. Under a sufficiently magnifying power, the transverse lines are also visible in several parts of such a preparation. In some places they are close together; in others, at a distance from each other: some are continued across several fibres; others have an irregular course somewhat like that of a line of mortar in a brick-wall.* Retzius has not succeeded in ascertaining how these lines are produced, but presumes, that if the enamel-fibre itself be an inorganic mass which is surrounded by an organic capsule, they belong to the latter and not to the former.

The enamel-fibres rest with one extremity on the membrane mentioned above, which is pressed closely on the surface of the dental bone. In human teeth Retzius saw distinctly, that this surface formed a number of small points, and between these were small, slight, but tolerably regular indentations, in which the enamel-fibres terminated. In man, the fibres support themselves on this surface at different angles; the lowest are generally transverse, and those which form the masticating surface of the

* Plate A. 1. Fig. 1.

tooth more perpendicular. In some parts of several teeth they are curved in various ways. They are somewhat larger at the outer than at the inner extremities, but in a degree which is not perceptible without the aid of the micrometer. In the crown of the human molar tooth, a number of fibres are wedged into the outer part of the enamel, but do not penetrate to the surface of the dental bone. Retzius has also seen a similar arrangement in other teeth, as for instance in the long, straight sides of the molars of the horse, and of the ruminating animals. In some of the mammalia the enamel-fibres are extremely indistinct. Retzius could seldom find them in amphibious animals and fishes ; but where they presented themselves distinctly, they were but slightly dissimilar to those in the human tooth.

A glass which magnifies three hundred times is necessary in order that the enamel-fibres may be distinctly observed : they are then seen ranged, side by side, like the wax tubes in the honeycomb, and like these they are hexagonal.*

If the enamel of a well-formed human tooth, which has not been worn away by attrition, be examined under a good glass, a number of elevated, undulating lines are observed on it running parallel from side to side, which are so delicate and so close together, that Retzius says he counted not less than twenty-four of them on an incisor, in the space of a Parisian line. They are most beautiful and closest together on the outside of the incisor, canine, and single molar teeth ; and are less distinct and more apart in the tricuspides. They do not run merely on the outer side of all these teeth, but are con-

* Plate A. 1. Fig. 4.

tinued round their crowns, though internally they are less distinct and less regular. Leeuwenhoek was acquainted with these lines, and believed that they marked the stages of the progress of the teeth through the gums. From examining a fossil horse-tooth, in which they were very large and plain, Retzius comes to the conclusion that they are formed from the enamel-fibres having united into belts, of which the inner rests on the tooth-bone, whilst the outer projects beyond that next to it. The enamel is first deposited on the extremity of the crown, or on the apices of the masticating surface; round this first deposit the next succeeding one forms a conical belt, which is again in its turn surrounded by another, and so on till the enamel is completed. In milk-teeth Retzius could not succeed in ascertaining that any of these rings existed.

In the interior of longitudinal fractures, or of polished longitudinal sections of enamel, two other appearances are observable. One consists of a sort of generally brownish parallel lines, which in teeth with their crowns not yet worn down, curve round the coronal apices of the dental bone; but which towards the sides, particularly in teeth with wedge-formed crowns, run nearly parallel with the axis of the tooth. Some of the coarser of these lines are perceptible to the naked eye. They appear to be the traces of different stages in the formation of enamel, and are analogous to the lines running round the cavity of the pulp in the dental bone. Schreger found that horizontal transverse sections of enamel presented three different belts or layers—an external gray one, a milk-white middle one, and a third gray like the first, in contact with the dental bone. These layers, says Retzius, are obviously the coarse lines mentioned above, or several fine ones in conjunction.

The second set of appearances above alluded to, is that of short, white, generally curved streaks, broad in proportion to their length, which are hardly perceptible to the naked eye, but which may be easily seen with the aid of a lens : at the end of the enamel, towards the neck of the tooth, they strongly incline outwards, and in the crown are turned towards each other, as it were, in an upright position. They are only visible under a slight magnifying power on a dark ground, and run sometimes in the same direction as the enamel-fibres, and sometimes in a different one. Under a full light they disappear, and in their place, by the aid of a glass of considerable power, is seen a sort of very faint broad streaks, formed by the meeting of the parallel shadows of the transverse lines of the enamel-fibres. Retzius found them in the enamel of most of the mammalia which he examined, and in greater quantity than elsewhere in the rings on its surface.

At its junction with the dental bone, and also in some other parts, the enamel almost always presents a number of delicate chinks, which appear to arise from its fibres shrinking from each other. Where this has taken place, they often present a dentated appearance like the fibres in the crystalline lens. When thin sections of a tooth are left for some hours in a solution of caustic potash, groups of these chinks are observed in different parts of them. This fact confirms Retzius in the opinion that the enamel-fibres are surrounded by delicate capsules of organic matter. The chinks were particularly remarkable in the enamel of the teeth of the *Balistes Vetula* and *Sparus Rondeletii:* they were here very numerous, almost regular in their course, and somewhat similar to the tubes in dental bone.

The *Cortical Substance*, like dental and other bone,

consists of cartilage and osseous earth. From the cartilage of human teeth, of which the osseous earth has been dissolved in acid, the cartilage of the cortical substance may be separated in the form of a membrane, which is thickest at the end of the root: in human teeth it appears to have less consistence than the cartilage of dental bone. Viewed under the microscope, it presents the same cellules or so called corpuscula as the proper osseous substance, dental bone, and most cartilaginous structures. It was less easily dissolved in boiling water than that of dental bone, and retained several earthy granules after those of the latter had all disappeared. When either recent or dried cortical substance, polished or in fine slices, is examined with a good lens, a number of white, crowded points, almost invisible to the naked eye, are discovered in it, which, on being further magnified, show themselves to be the cells above-mentioned, deriving their white colour from the osseous matter they contain. As in dental and common bone, numerous tubes pass into and from them, widening as they enter, and giving them the appearance of irregular stars. These tubes have numerous communications with each other, partly direct, and partly by means of branches $\frac{1}{1000}$ to $\frac{1}{5000}$ of a line P. M. in diameter: some of them pass immediately from one cell to another, precisely as in the dental bone. The osseous cells are of various forms and sizes; some are elongated, so as to look almost like tubes; some are nearly round: their average size Ritzius found to be $\frac{1}{150}$ line P. M. In sections made transversely to the axis of the tooth, it is plainly seen that the osseous cells are arranged in parallel lines or concentric rings, some fainter than others, or that the cortical substance is deposited in delicate, coherent layers.

In the human tooth the cortical substance is an ex-

tremely thin stratum, taking its origin in most teeth with a complete root at the neck where the enamel terminates, and increasing in size as it descends towards the extremity of the root, where it is generally thickest. In young teeth, of which the roots are not yet fully developed, it is so thin that the osseous cells in it are not perceptible; and it has merely the appearance of a delicate membrane. On the other hand, the older a tooth is, and the more the cavitas pulpæ is closed, the thicker is the cortical substance at the end of the root, where it sometimes forms a considerable enlargement, or what is commonly called an exostosis. Retzius has seen a case where this increment was of the length of three lines at the root; and has also examined a wise tooth, where the cortical substance was so plentiful at the neck, that it formed a sharp projecting border turned towards the crown, and gave to the whole tooth an uncouth appearance. In teeth projecting considerably from the alveolus, and which have not been worn away, Retzius found it sometimes thicker than the dental bone itself, and this he thinks is particularly the case in those teeth which have been loosened by the scurvy, or by the use of mercury.

Retzius has not only examined the teeth of the human subject, but also those of the *Cercopithecus cynomolgus*, *Felis lynx*, *Canis familiaris*, *Erinaceus europæus*, *Sorex fodiens*, *Castor fiber*, *Lepus borealis*, *Bradypus tridactylus*, *Dasypus tricinctus*, *Ovis aries*, *Bos taurus*, *Equus caballus*, *Elephas indicus*, *Hippopotamus amphibius*, *Rhinoceros indicus*, *Sus scrofa*, *Phoca annellata*, *Trichechus rosmarus*, *Delphinus delphis*, *Crocodilus sclerops*, *Python bivittatus*, *Squalus cornubicus*, *Sparus rondeletii*, *Anarrhichas lupus*, *Cyprinus idus*, *Esox lucius*, *Gadus molva*, and *Balistes vetula*.

Cercopithecus Cynomolgus.—In the monkey the main

tubes are of about the same size as in the human subject. Retzius only saw branches at the extremities of the tubes which belong to the crowns of the molar teeth. Here and there in the neck a larger branch is given off; and down at the root all the main tubes are surrounded by extremely delicate, subdividing, and thick-set branches, given off in almost opposite directions, of which those which run towards the crown are the largest. They are for the most part curved like a bow, and in such a way that the concavity of the arch is turned towards the *cavitas pulpæ*. The undulating curvatures of the main tubes themselves seemed to be longer drawn out and less numerous than in man.

In the monkey, the cortical substance begins where the enamel terminates. The cells are somewhat larger and closer together than in man; but are also of several different forms, as triangular, circular, oblong, with pointed extremities, &c. The majority of the tubes which terminated in them came from without, and the greater number opened into that side of the cells which looked from the axis of the tooth. Most of the fine calcareous tubes opened into the cells without any particular widening at the basis.

Felis Lynx.—Of the lynx he examined two canine teeth, and two of the most posterior molar teeth: they had all been kept for some time in alcohol. In both kinds of teeth, the tubes appeared of the same size as in man. In the canine teeth, which, although the animal was very young, were nearly closed at the end of the root, the tubes, towards the external part of the whole tooth, presented numerous and beautiful branches: these branches divided and subdivided, forming at length a net-work like down. In many parts lay, as it were in scattered rows,

oblong cells filled with osseous earth, and branches from the tubes wound round about them. When the preparation was laid for some time in turpentine-varnish, it became nearly transparent; the branches of the tubes were then rendered very incomplete, and were only apparent in some few places: in the other parts, the main tubes appeared to terminate abruptly, and to give off no branches, or there were only visible the dull streaks which they had left behind them.

In the *lynx*, the *dog*, and the *hedge-hog*, the cortical substance existed only as a thin layer at that part of the tooth which was not invested with enamel, and it gradually diminished, and then terminated towards the border of the enamel. In an incisor tooth of an old dog, which had been much worn away, it was very thick round the extremity of the root, but could only be traced to a very short distance. In the canine tooth of a full-grown lynx the cells were on the whole somewhat smaller, and also rounder than in the human subject. The fine calcareous tubes had generally almost straight trunks, which ran tolerably parallel to each other, and horizontally towards the sides of the teeth. The cortical substance was thickest at the end of the root, and closed the *cavitas pulpæ*. Nevertheless, this cavity still existed, and contained a red pulp, which was continued as far as the apex of the tooth. In connexion with this, the cortical substance at the root was perforated by several canals, which in a converging direction were prolonged towards the end of the cavitas pulpæ. The diameter of these canals was about $\frac{1}{63}$ line, P. M. In a rugged molar tooth from the upper jaw of the same animal, the small osseous tubes presented in several places similar parallel prolongations to those in the canine tooth; in other places they were absent. On

the sides and between the roots the cells were the same as in the canine tooth ; but round the ends of the short roots they were in the highest degree irregular. Several were two or three times larger than those just mentioned ; they ran into each other, and intruded as it were into the region of the dental bone. Here also were found similar but larger canals, running to the end of the *cavitas pulpæ* : these canals contain probably the blood-vessels, which furnish nourishment to the pulp.

Canis familiaris.—The teeth of the *dog* were found to be like those of the lynx. In the roots of the incisor teeth the tubes were very angularly curved, curled as it were, and splitting into lengthy branches.

Erinaceus Europæus.—In the *hedge-hog* the main tubes are of the same thickness as in the preceding, but shorter in consequence of the smallness of the teeth. In the incisor teeth they are, as it were, drawn out, and faintly undulating, with only a few larger curvatures ; on the other hand, the branches here are extremely evident; they curve very beautifully in almost all directions, more particularly towards the crown and the root; but in the crown itself the curves are generally turned towards the surface. The branches are probably so particularly evident in these teeth, because they continue thicker for a longer distance than in different other teeth.

Whoever wishes to convince himself of the ramification of the tubes in dental bone, cannot better or more easily do so than by examining a thinly-filed longitudinal slice of the incisor tooth of a hedgehog. In the crowns of the molar teeth, the main tubes are straighter, in the roots curled and undulating ; the particularly short trunks terminate immediately after their commencement in long, thick branches, running towards the surface of

the tooth, and giving off in their course other curved branches above and below, which cross the contiguous tubes.

Sorex Fodiens.—In the *shrew*, in which the teeth are still smaller, (the dental substance in the incisor teeth near the root being in some parts only $\frac{1}{10}'''$ P. M. thick from the cavitas pulpæ to the surface,) the tubes are in the same proportion very short. Still their diameter at their commencement is equal to that in the human subject; and their outer extremities lose themselves in equally fine points or branches. They accordingly diminish very rapidly, and in these places present no longer the appearance of cylindric tubes, but of small, sharply-pointed cones, which give off a number of proportionally thick branches, which again subdivide several times. In the apices, too, of the incisor teeth, which are so peculiarly formed in this animal, the ramifications of the main tubes are particularly well seen—some of the branches being small, short, and their direction transverse; others being extended, longer, and longitudinal in their course.

Castor Fiber and *Lepus Borealis.*—In the *beaver*, as well as in the *hare*, the main tubes are of the same diameter as in the preceding, and present the most remarkable and extensive ramification in the whole length of the tooth. In the incisor, as well as in the molar teeth, most of the tubes present a curve like the letter *f*. In the incisor teeth most of the branches are given off from that side of the main tube which is turned towards the crown: in the molar teeth, on the other hand, the most numerous and the largest bundles of branches appear to have their origin on the side towards the root, and along the root of the tube. The main tubes lie very close together, particularly in the crown, so that the intermediate spaces

are scarcely wider than the diameter of a single tube; but towards the root they are further apart, and the branches are seen here more particularly to turn towards the root. In the roots only is the direction of the main tubes transverse; near the masticating surface, they approach the direction of the axis of the tooth. Of the ramifying tubes near the root, in a *dens incisivus major* of a hare, a drawing is given, Plate A. 2. Fig. 2. *a*. The most inferior tube, Fig. 2. *b*, is isolated from the rest in order that it may be represented more clearly. In the longitudinal streaks running in the direction of the axis of the tooth, which give to some of these teeth an appearance as if they were composed of cones contained one within another, (See *Heusinger Histologie*, Part I. Fasciculus 2nd, p. 200,) no certain curvature of the tubes could be discerned, nor any evident corpuscules, or osseous cells, but only thin layers of a connected, whiter, more opaque substance. In the singularly constructed molar teeth of the beaver and of several other rodentia, the tubes in the proper dental bone are just as regular, and present the same forms, and the same ramifications, as in the incisor teeth.

In the *beaver* and *hare* the *cortical substance* was only found on the molar teeth, where it exists principally in the furrows which the enamel and the dental bone internally make towards the cavity of the pulp. The cells in this cortical substance were extremely irregular in the beaver; some held $\frac{1}{85}$ line P. M.; some were five or six times larger: some of the fine tubes radiated from a centre, others were parallel; but the parallel ones ran in more various directions. On the external side of the molar teeth of the beaver an extremely fine layer of cortical substance was recognised; on the other hand, the

part of the tooth which was enclosed in the alveolus was completely covered with enamel. In the incisor teeth of the beaver, as also in those of the hare, the cortical substance was wanting.

In the beaver and hare, and probably in all the rodentia, the teeth are invested with *enamel* in their entire extent. It is well known that these teeth, particularly the incisors, continue to grow during the whole life of the animal without closing at the alveolar extremity; so that one of them which has not been worn away, owing to its having grown in a wrong direction, becomes much longer than it was when it first projected from the alveolus. The enamel in these animals continues to be formed as long as the teeth continue to grow; (*Oudet, Experiences sur l'accroissement continu et la reproduction des dents chez les lapins*, 2. *mem.*,) whence we may come to the certain conclusion, that it is not formed alone within the proper *folliculus dentis*, but that an organ for its production may continue to exist at the bottom of the alveolus itself during the whole life of the animal. The attention of Retzius was first called to this fact on his examining a longitudinal section of the third molar tooth (three inches and a half long, P. M.) out of the lower jaw of an old horse:—he found that even here the coating of enamel proceeded to terminate at the extreme border of the roots; two roots of four lines in length, but open at the end, were already formed; but even these were covered, as above described, with enamel. In order to ascertain more exactly whether the enamel in this case had actually been formed after the tooth had burst through the dental sac, Retzius instituted a comparison between this and the same tooth in another horse, whose third milk-molar in the lower jaw was about to be shed, and to be succeeded by its lengthy

substitute, and he found that the latter was the shorter by nearly an inch, and did not display the slightest trace of the formation of a root. If we assume that it might still have grown a quarter of an inch before bursting through the dental sac, (which, however, round the crown was already absorbed,) three quarters of an inch of the enamel investment still remains, which had been formed after the dental sac had been burst through in the alveolus. But though, as we have seen, the enamel in certain horses' teeth may be deposited as far as the divided roots, this is not universally the case in this class of animals. In the molar teeth of very old horses, with long roots, the latter are only covered with enamel at the commencement; and in the milk-molar of the new-born foal, which have already divided roots, the enamel terminates at the commencement of the latter.

The red colour in the incisor teeth of the beaver is derived from the enamel. Retzius cannot understand how that excellent writer, F. Cuvier, was so far deceived on this point, as to believe that it belonged to the cortical substance, seeing that these teeth present no cortical coat whatever. Cuvier's words are: " In fact, the colour of the anterior part of these teeth depends on a very delicate layer of true cortical matter, as I have assured myself by repeated particular experiments; and it only becomes brown on that part of the tooth which is not covered by the gums." The incisor teeth of the beaver, and probably of all " glires," are invested with enamel. In the beaver, Retzius observed this peculiarity, that the above-described transverse lines on the enamel-fibres here run with particular regularity in straight parallel lines, which, at equal distances from each other, intersected the streaks between the enamel-fibres at oblique angles,

forming oblique, equilateral squares. The red colour has its seat in this enamel, but in only a very thin layer of it. Just beyond the border of the gum the thickness of this layer was $\frac{1}{150}$ line P. M.; nevertheless, in an extremely thin slice, and magnified several hundred times, it was strongly marked, and had a well-defined border towards the white part of the enamel.

Bradypus Tridactylus.—In the *Bradypus*, the tubes are very different from those in the preceding animals. The substance which properly corresponds to the solid dental bone consists here of merely a thin cylindric shell, which in newly-formed teeth is probably closed in the crown, but which was wanting there in all the teeth of these animals examined by Retzius. The cylindrical shell, which is consequently formed from the proper solid white dental substance, is filled towards the crown with a yellowish or brown, half-transparent, softer, almost horn-like substance, which terminates internally towards the end of the pulp.* In young subjects this plug, if it may so be called, is very short; in older ones, it is longer, and is continued through half or two-thirds of the whole tooth. In this internal, yellowish, horn-like substance, a sort of coarse tubes are generally seen of $\frac{1}{5}$ to $\frac{1}{10}'''$ P. M. in thickness, which proceed from the surface contiguous to the pulp, rise towards the crown, and are curved outwards in such a manner that the middle ones are generally parallel to the axis of the tooth, whilst the external ones turn more towards the sides, just as in certain teeth of fishes, or

* Of the shell here mentioned, F. Cuvier observes, " *Toutes les machelières ont la même forme, sont cylindriques et leur partie centrale se compose d'une substance plus tendre que celle qui l'environne, et qui est analogue à l'émail, quoique moins dur que lui.*"

somewhat as the jets of a fountain. These tubes are not uniform: some are dilated in one place, and immediately afterwards contracted, or are large in one part and small in another. They give off several larger and less irregularly winding branches: between them is here and there a cavity, into which delicate winding passages open, just as the small winding passages terminate in the calcareous cavities in the more delicate structure of bone. Finer tubes, similar to those usually found in dental bone, are given off from the larger ones, and are continued as far as the shell which is composed of the firmer white dental substance. The larger tubes, too, terminate in the more regularly arranged tubes which belong to that substance; but precisely at this junction they become minute nearly of a sudden, make at the same time two particularly definite curvatures, and then nearly straight run in an oblique direction; some towards the crown, and some towards the sides of the tooth. That portion of the tubes situated in the above-named white substance, may be regarded as analogous to the tubes in the dental bone of other teeth, and have the same diameter as the corresponding tubes in the human subject. The most perceptible branches are seen in the white substance near the junction above alluded to: they run nearly at right angles to the axis of the tooth: a part of the branches turn towards the crown, others towards the root of the tooth to which they belong. In the crown they appear, at their outer extremities too, as plainly ramifying; but besides, under a three hundred to a four hundred times magnifying power, these main tubes, so to call them, which belong to the white substance, are as it were covered with a downy net-work, composed of extremely minute tubuli, of which the further course could not

be traced by the eye. When we have got beyond that part of the dental cylinder, which towards the crown is filled with the above-mentioned plug of horny substance, we find that the tooth is hollow for a considerable distance. In this hollow part, the main tubes towards the cavitas pulpæ internally appear to be as it were distended at their extremities. In this part of the tooth, these same trunks have some of them the form of an *f*, and are also more scattered, and more evidently provided with large branches than those nearer the crown.

The teeth of the *Bradypus* are covered with cortical substance as far upwards as towards the masticating surface, and it seemed to Retzius as if the ends of the tubes in the proper osseous substance passed in many places into the cortical substance, and united with the tubes of the latter; he thought, too, that he perceived that several of the tubular branches passing from the dental bone into the cortical substance, opened into the small calcareous cavities of the latter. This arrangement was frequently investigated, and appeared clearly to be as just described, although Retzius was at first as much inclined as possible to doubt its reality.

It results then from the above facts, that the teeth of the *Bradypus* present a very low degree of development, and approach, in their internal construction, as comparison will show, a type of formation which seems properly to belong to certain fish, particularly to the pike. It is also probable that the dental tissue in the orycteropus is analogous to the internal soft dental substance in the *Bradypus*. That direct communications exist between the tubular systems in the two constituent formations, developed at different periods, that is to say, in the dental bone and cortical substance, seems to lead to the conclusion that certain canals

open into the former after it has been fully formed, and that hence it is not altogether impossible that a formative action may go on in it after its first production. On the teeth of this animal there is no *enamel.*

They are invested in their whole length with *cortical substance.* The cells nearest the dental bone are nearly round, and about $\frac{1}{140}$ line P. M. wide; those lying more externally are generally oblong, $\frac{1}{85}$ line P. M. long, and $\frac{1}{250}$ broad. The fine tubes which opened into them seemed to form large bundles running from them in an external direction. They were extremely delicate; were not dilated at their opening into the cells, on the external sides of which they were nearly parallel; and for each cell they were so numerous that Retzius could not count them with any degree of certainty. The cells themselves lie very close together.

Dasypus Tricinctus.—In the small, cylindric, hollow teeth of the *dasypus tricinctus,* which are open towards the root, the main tubes were not more than half as thick as in the human subject: those occupying the internal part of the crown were more winding, more diverging, and less parallel than those at the sides; the latter ran nearly straight, with a single faint curvature, of which the convexity was turned towards the crown and the axis of the tooth. The inner tubes of the crown did not display any ramification; but all had branches towards their outer extremities. In the teeth of the *dasypus,* Retzius only found one dental substance; neither enamel nor cortical substance were present.

Dasypus Novemcinctus.—On the teeth of this animal no trace of cortical substance, or of enamel, could be found.

Ovis aries.—In the incisor teeth, as well as in the thin folded plates of the osseous substance of the molar teeth

of the *Sheep*, the main tubes present delicate undulating curlings. In a section of an incisor tooth, which was cut from before backwards with the axis of the tooth, these main tubes presented three more considerable curvatures; and between these were ramifications, differing in extent, which indicated different stages in the formation of the tooth. To the naked eye, too, the substance appeared as consisting of three layers, one lying before another. In the external layer the main tubes were straightest and most regular; in the middle one, more curved, and in the internal one, most so. At the border, between the external and inner one, that is to say, immediately within the external large layer of tubes, was situated in the whole length of the tooth, except at the crown, a row of oval bodies which, on closer examination, were found to be small cavities filled with osseous earth, of which the largest was $\frac{1}{56}'''$ par. m. wide, and $\frac{1}{17}'''$ long. The tubes wound close round the pariates of these cells, giving off several branches which also surrounded them, and some of which communicated with them. At the outer border of the preparation, or on the external surface of the tooth, appeared a number of thickset, calcareous, scale-like corpuscules, between and in which the minute terminations of the tubular branches seemed to be lost. These corpuscules, as well as the small calcigerous cavities just mentioned, presented a white appearance when viewed on a dark ground.

The tubes in the incisor teeth had evidently large branches from their commencement in the *cavitas pulpæ*; and, moreover, in the whole course of the main trunks, and of the principal branches, minute ramifications were observable. The main tubes in the external third of their course were not half so thick as at their com-

mencement in the *cavitas pulpæ*, and the concavity of their curvatures was in this part generally turned towards the crown. More internally, several branches ran in a vertical direction towards the main tubes.

In the dental substance of the molar teeth the tubes present no large curvatures; but at the outer wall *one* was observable, of which the convexity was turned towards the crown and the axis of the tooth. In the tubes lying next to the crown this curvature was nearer to the external enamel; in those more in the neighbourhood of the root, it was nearer the middle of the tube. The tubes belonging to the alveolar part of the tooth were, for the most part, of the form of an *ʃ*. All these tubes gave off branches in their entire course; but those were the most conspicuous and most numerous which formed the termination of the main tubes towards the enamel. Most of the ramusculi proceeding from the outer extremities of the main tubes, appeared to be given off by the concave sides of the latter, which are turned towards the root; and they were themselves curved towards the root.

In the *Sheep*, Retzius found only a thin layer of *cortical substance* on that part of the teeth which is covered with enamel; it was more plentifully deposited round the ends of the roots which were nearly closed, and also in the indentations of the crown. The cells as well as the tubes were rudely and very irregularly formed. In the thin lamella which invested the enamel, the cells seemed more to resemble large, reticular, vascular glands than proper cavities: the tubes were large, and their course irregular. In the cortical substance round the roots, some cells were oblong, very angular, and drawn out to a considerable length; and, moreover, a number of rude canals tolerably parallel, but very wide apart, were

found running from within outwards. The above-mentioned gland-like cells were about $\frac{1}{85}$ line P. M. in diameter: the thickness of the large tubes was $\frac{1}{3}$ less. It was particularly remarkable that there were frequent and considerable communications between the cortical cells and the cells in the outer part of the dental bone. The cortical substance in the dental furrows was porous in the highest degree, and consisted of still more irregular tubes and cells, than in the above-mentioned places.

Bos Taurus.—In an incisor and in a molar tooth of the *Ox*, Retzius found the organisation to be very similar to that in the sheep. The molar tooth being an old one, the small cavities for the foliform prolongations of the pulp were found to be nearly closed by the dental substance. In this last-formed dental substance the tubes were very undulating, and in different directions; in the midst of it were several yellow bodies lying longitudinally in rows, and the tubes wound spirally round about these. In the incisor as well as in the molar tooth, the main tubes displayed a plentiful ramification; some of the branches being long and generally parallel; others short, transversely-running, curved, delicate, and forming, as it were, a downy net-work. The extreme ends of the tubes in the neighbourhood of the enamel showed the same mixture of extremely fine osseous corpuscules as in the sheep. The tubes also resembled those in the sheep with respect to their undulations, curvatures, and gradual diminution. The diameter of the main tubes, near the *cavitas pulpæ*, varied from $\frac{1}{900}'''$ to $\frac{1}{1000}'''$ P. M.

The *cortical substance* in the ox is much thicker than in the sheep: the large tubes were here found to ramify, and ran in an almost horizontal direction towards the sides of the tooth. The cells were smaller and more irre-

gular than in the sheep. They lay very close together; approached the circular form; and were about $\frac{1}{193}$ line P. M. in diameter. It has been customary to consider the so called cement or cortical substance as only belonging to the crown of the teeth of ruminating animals, or to that portion which is invested with enamel. That this view is erroneous results from what has been stated respecting the cortical investment of the teeth of sheep; but it is still further refuted by an examination of the shapeless, tuberous roots of certain ox-teeth. The deformity in these cases arises, as Retzius has found, from a too great deposit of cortical substance from the alveolus. Some teeth of this kind are preserved in the collections of the Carolinian Institution, and of one of these Retzius has given a drawing to illustrate the subject. (Plate A. 1. Fig. 10.)

Equus Caballus.—In sections of fully-developed, permanent, incisor teeth of the *Horse*, cut from before backwards, longitudinally to the cavitas pulpæ, the tubes nearest the masticating surface, which were generally parallel with the axis of the tooth, were of the form of the letter *ƒ*: more inferiorly in the crown the succeeding ones resembled an ε; and those which belonged to the extreme part of the root, a C, of which the convexity is turned towards the crown. In younger teeth which were not yet filled up in the crown, one or two curvatures were wanting. The undulations of the tubes were, so to say, more stretched out than in the human subject. At their inner extremity the diameter of the tubes varied between $\frac{1}{800}'''$ and $\frac{1}{300}'''$ P. M. Their diameter diminishes considerably before they terminate in branches at the outer part of the tooth. In the middle of their course, their diameter appeared to be $\frac{1}{3}$ less than at its commencement. In the first or inner half of their course the tubes lie so close

together, that the space between two of them is no larger than the width of one of them: here Retzius could discover no branches; but about the middle of the course of the tubes, which at the sides of the tooth correspond to the central curve resembling an ϵ, branches begin to be seen, some presenting the appearance of small, transversely-running streaks, which are bent inwards; others being longer, and, as it were, stretched out. As the tubes proceed towards the surface, the branches become more and more numerous, are most plentiful on the convex sides of the main tubes, though in several places they are equally numerous on both sides, and frequently form very acute angles with the main tubes. Hence most of the branches lie closer, as it were, to the main tubes, than in the above-mentioned animals. On the external side of the tooth the branches ran in almost opposite directions. Under a three-hundred-and-fifty-times magnifying power, the most delicate branches appeared to be as close together as the filaments in down. In several places the minuter branches seemed to terminate in small angular cells, similar in appearance to the small calcareous cells in bones. These cells were particularly numerous in the external part of the tooth, and most so immediately beneath the enamel, where the greatest number of minute branches terminate. These minute branches wind between the calcareous cells, and terminate partly in them. There were also found here a number of extremely minute passages, running from cell to cell, and forming an anastomosing net-work, between the branches as well as between the calcareous cells. (See Plate A. 3, Fig. 6.)

These calcareous cells are much more minute than those which are found in bone.

In the incisor teeth of the horse, too, are found several somewhat opaque streaks, running parallel to the cavitas pulpæ, which resemble the annual circles in a tree. These did not result, however, here alone from certain parallel curvatures of the main tubes, but principally from similar calcareous cellules, which presented themselves in the same track in the greatest part of the length of the tooth. (See Plate A. 3. Fig. 6.)

Round these cellules wound also numerous ramusculi, and seemed to terminate in them. In the dental substance, which fills the cavity of the pulp from above, similar cells are found, but much larger.

In a milk incisor-tooth the tubes were much more conspicuous than in the permanent ones. The trunks here evidently divided in many places in a furcated manner. The small branches were given off from the trunks at very short intervals from each other. Where they gave off branches the trunks were in many places dilated, as it were, and thus presented an unequal appearance. The branches ran partly stretched out, and inclining at an acute angle towards the external ends of the main tubes, and in part transversely towards these in short arches. Osseous cells were everywhere scattered throughout the intermediate spaces; but here, too, they were most numerous in the surface of the tooth, and under the enamel.

The main tubes were most undulating near the cavity of the pulp; as they advanced towards the surface the undulating curvatures gradually diminished.

On the posterior side of the neck of the tooth were found, along the axis of the tooth, longitudinal streaks, which arose from parallel curvatures and furcated divisions of the tubes. The streaks did not here owe their

origin to any accumulated cells. The calcareous cells were larger than in the permanent teeth.

In the permanent molar teeth of the full-grown horse, the main tubes in the dental substance were not so close as in the incisor teeth, and maintained exactly the same diameter till very near the enamel, which here, singularly enough, invests the whole extent of the dental bone as far as the ends of the roots. The branches were thicker on leaving the trunks, and did not run so close to these as in the incisor teeth. The undulations were better marked, though drawn out and irregular. Most of the main tubes were considerably extended towards the crown, assuming the form of an inverted *ſ*, with a considerable prolongation of the lower extremity. The outer or coronal extremity of the main tubes was curved away from the axis of the tooth in an almost transverse direction. In this transverse part several of the tubes seemed near their termination to make one or two larger curvatures. In the neighbourhood of the root, most of the tubes assumed a more transverse position, as in most other teeth. The greatest part of the cavities of these teeth was closed, in the neighbourhood of the masticating surface, by dental bone, and the cavity of the pulp was very narrow as far as the commencement of the root. It was filled with a more yellowish, brown, osseous substance, which nearer the masticating surface was dark brown, probably from colouring matter which had penetrated from the food without. As the tubes in this more recent dental structure ran almost directly towards the masticating surface, where their ends were worn away by attrition, and were denuded of all covering, it is easily conceivable, that during mastication, colouring matters of different kinds penetrate this substance more easily than any other.

The *cortical substance* in the horse presents more large tubes than that of the ox; they are about $\frac{1}{50}$ line P. M. in width, run horizontally from without inwards, and divide into branches. From these tubes, which may be compared, to a certain extent, with the medullary canals in osseous substance, innumerable minute branches are given off, which are as thick as the hairs in the finest nap. Between these are situated small, short, oval cells of about $\frac{1}{200}$ line P. M. in length. The tubes which leave the latter are so minute and so close together, that here, as in the sheep, such a group assumes the appearance of a vascular gland several times larger than the cell itself; Retzius succeeding in seeing these knots of tubes whilst the preparation was being varnished with turpentine. After having been thus steeped, the preparation was almost opaque. Immediately after it had been penetrated by the turpentine, the above-mentioned knots of tubes presented an appearance almost similar to that of the balls of the *Conferva Aegagropila*, but still one ran into the other. This appearance, however, was not long kept up: the minute tubes were shortly filled with varnish, and then they disappeared altogether. A few minutes afterwards the large tubes and the cells (filled for the most part with varnish) were all that was to be seen. It was not till now that the small cells could be properly seen, and, from the appearance which they presented, no one would have supposed that any tubes or vessels opened into them. The cortical investment was very thin round the roots of the molar teeth; on the other hand, it was almost a line thick in some places round that part of the crown which is not surrounded by the gum. In young molar teeth, just before the period of extrusion, the enamel furrows were quite filled with cortical substance, and a thick layer was already deposited on the

sides of the masticating surface, whilst on the other hand this same substance was nearly altogether wanting on two thirds of the length of the tooth, nearer the root. The outer surface of this recent cortical substance was already porous, and on the border, towards the root, it was deposited in small, separate, undulating rings.

Elephas Indicus. — Of the *elephant*, Retzius only examined sections of the tusks. For the investigation of their tubular structure, slices were taken out of the hollow alveolar end, because in them the whole extent of the tubes from their commencement in the *cavitas pulpæ* to their termination towards the cortical substance can be surveyed in a smaller compass. For the examination of the concentric rings, he used more transversely cut sections, which were taken from nearer the apex of the tusk.

The main tubes at their commencement at the *cavitas pulpæ*, and afterwards in their entire course, are much smaller than in the human subject: on an average they present a diameter of $\frac{1}{1000}'''$ P. M. Their distance from each other scarcely amounts to the breadth of a single tube. They are undulating, though to an almost imperceptible degree, but, on the other hand, they present a number of nearly angular parallel curvatures, of which some follow each other at a distance of $\frac{1}{30}'''$ P. M., some at rather a greater interval. These curvatures point in different directions—some upwards, others downwards; some to the right, others to the left: or, to express it more properly, they appear to run on two planes which cross, or are at right angles to each other. In these curvatures the concentric rings are formed, of which more will be stated below.

In these, as in most other teeth, the calibre of the tubes

diminished as they approached the external parietes, and formed furcated divisions at very acute angles, thus filling the larger space which they had to occupy the further they were removed from the axis of the tooth. Besides these grand divisions, they gave off smaller branches following close on each other, of which Retzius could not trace the course, because they filled so rapidly with the fluid in which the preparation was immersed, that they became as clear as the spaces between them. Besides these short tubes which fill up, in a great measure, the intermediate spaces, the latter were occupied, more than in any teeth which have previously been described, by small, white, angular points, or calcareous cells of different sizes, which lay strewn about like grains of white sand. Then again, as well as these scattered and less thick-set calcareous cells, there were also other larger ones, more crowded and connected together, which lay in the above-mentioned parallel curvatures. In transverse sections of the canine teeth of the elephant, they form beautiful, regular rings round the cavity of the pulp, or the axis of the tooth, of which some stand about $\frac{1}{30}$ P. M. from each other, and which are so minute that they could not be seen with the naked eye. In longitudinal sections they form whiter, longitudinal, parallel streaks. These streaks and rings are not, however, those which Cuvier and others have described, for the latter are visible to the naked eye, and they shew themselves as broad, darker or lighter concentric osseous layers; they are also not to be confounded with the streaks in ivory, which appear in a transverse section running in arches from the centre to the periphery, which cross each other, and in longitudinal sections appear as unequal, but generally parallel stripes, which here and there are cut into rhomboid

figures, as it were, obliquely, and which partly run into each other. The latter streaks corresponding to the arched ones which cross each other obliquely in the transverse section, arise, like these from the refraction of the rays of light, by the parallel curvatures of the main tubes. They appear in longitudinal as well as in transverse sections from this cause, that the parallel curvatures, as has been already remarked, run in two planes, which intersect each other, or, as it does not seem improbable, they run spirally.

In the elephant, Retzius only examined the *cortical substance* which invests the canine teeth. The cells varied little in size or form; some were oval, but the most were almost round: their size was about $\frac{1}{280}$ line P. M. The small vessels terminating in them were so minute, that they could not well be distinguished. What principally characterises the organisation of this substance is the almost parallel and horizontal running, undulating tubes, which evidently approach the appearance of the tubes in the dental bone. The larger of the tubes were $\frac{1}{840}$ line P. M. broad; the smaller $\frac{1}{1000}$ line. Although, when cursorily examined, they appeared to be continued from the surface of the tooth to that of the dental bone itself, Retzius found, on closer investigation, that this was not the case. They appeared to be continued partly because they had the same direction, and partly because the minuter terminations projected, as it were, beyond each other. As well in the outer as in the inner surface of this substance, they terminated in ends which became gradually finer, and which most internally were curved towards the wall of the dental bone. They gave off from their sides a number of larger and smaller branches, which entered into numerous communications with the conti-

guous ones: the larger branches were given off generally at an acute angle. It would have been doubtless interesting to have examined this substance in other parts, and particularly on the molar teeth; but Retzius could not procure any preparation of these.

Hippopotamus amphibius.—Of the *hippopotamus*, Retzius only examined the incisors, and for the investigation of their tubular structure, he chose here also slices which were taken from the border of the hollow alveolar extremity.

The main tubes did not lie so close here as in the elephant, but are of about the same calibre. As in the latter animal, they are scarcely perceptibly undulating, but make on the other hand a number of parallel curvatures, which, however, are not so close together as in the elephant. The branches were somewhat more distinct than in the teeth of the latter. The small calcareous cells which occupy the greatest part of the intermediate spaces, are much more thinly scattered than in ivory: they are partly larger, and partly smaller. In fewer parallel curvatures appear such deposits of calcareous earth as contribute to form the concentric rings in the tooth of the hippopotamus; on the other hand they formed a thick and constant layer on the entire surface of the tooth between the most external, minute branches, in which the ends of the main tubes terminate.

The concentric rings in the tooth of the hippopotamus are not so regular as in ivory: they are more abrupt, are undulating, as it were, and arise principally from the refraction of the rays of light in the parallel curvatures.

Rhinoceros Indicus.—In the *rhinoceros*, Retzius had only the opportunity of examining pieces cut longitudinally from the edge of the roots of a molar tooth. In

these the tubular structure was admirably demonstrated. He found the main tubes at their widest end $\frac{1}{117}'''$ P.M. broad. Although they were somewhat unequal, and showed here and there an extremely faint curve, they still could not be regarded as undulating. Like the main tubes in the alveolar ends of most teeth, they had an almost horizontal direction from the cavity of the pulp to the periphery of the root. As they proceeded in their course towards the periphery, their furcated divisions were very apparent, and they gave off moreover a great abundance of branches, of which many appeared distinctly to terminate in large calcareous cells. These lay thinly scattered in the interstices between the main tubes, which interstices, bordering on the cavity of the pulp, were of about the width of two tubes. A thick and compact layer of larger and smaller calcareous cells had its seat at the outer surface of the root, immediately under the cortical substance which invested it. Between these closely-situated, communicating cells, the extreme ends of the tubes wound in particular abundance, and seemed partly to terminate in these calcareous cells themselves, and partly to anastomose with branches from contiguous tubes. These anastomoses appeared in many places to form beautiful arches. In one or two places were larger groups of calcareous cells in the midst of the dental bone, which had, as it were, supplanted the main tubes. Round these cellular groups wound a number of beautifully-arched branches from the most contiguous main tubes, which themselves inclined somewhat towards them: these branches ran also straight to the cells, and terminated in them.

Besides the branches which are visible in great abundance, Retzius could see from thick-set, nearly alternately situated unevennesses on both sides of the main tubes, that these

unevennesses were derived from branches, which in these places were given off from the main tubes, but which were filled and rendered invisible by the varnish by which the preparation had been penetrated.

Retzius only examined the *cortical substance* in a molar tooth of the rhinoceros. The thin shell of this which covered the crown, as also the thicker one round the roots, presented thinly-strewn, large cells of various, and, as it seemed to him, irregular forms. Some were round, $\frac{1}{200}$ line P. M. broad; others were drawn out longitudinally, partly in the shape of tubes, partly as irregular figures: a number of tubes opened into all of them from every side. Round the circular cells the tubes which opened into them lay very close, and presented a radiated appearance.

Sus Scrofa.—In the *pig*, of which Retzius examined a small molar and two canines, he found the greatest diameter of the tubes to be $\frac{1}{555}$ P.M. They diminish only gradually towards the outer extremities, and do not become very minute until they reach the outer part of the tooth, where they are distributed into an irregular net-work of tubes and calcareous cells, and form the outer wall of the dental bone. They are but slightly curved, and are scarcely to be called undulating. Most inferiorly, towards the alveolar border, they are of the form of the letter C; near the middle of the crown they are almost straight and parallel with the axis of the tooth; and towards the masticating extremity, they present the form of an S. Their distance from each other is about the width of from one and a half to two tubes. Their divisions in an external direction are furcated and acutely angular. The branches thus formed run immediately after the division again parallel with each other. Moreover, along

the whole course of the main tubes, short branches are given off, of which Retzius traced some to dilated extremities which resembled calcareous cells. These short branches, lying on both sides of the main tubes, proceed in part almost transversely and curved over the nearest interstices, and run partly as serpentine or winding lines towards the outer wall of the tooth. Only a few calcareous cells were found in the interstices, and Retzius could discover no concentric rings. On the other hand, there were a number of very large, many-cornered cells, giving off numerous branches in the yellowish substance, which at the top of the tusk filled up the narrow cavity of the pulp.

In the *pig* the *cortical substance* presented nearly the same structure as in the elephant. The cells were of the same size and appearance, but the parallel, stretched-out tubes were somewhat larger. In the pig, this substance proceeds a little beyond the border of the enamel; but on the remaining surface of the latter it could not be discovered. Here, as in the human subject, it only forms an investment of the roots of the teeth.

Phoca Annellata.—Of the *seal*, Retzius examined longitudinal and transverse sections, both of the incisor and molar teeth. On no part of them could he discover an enamel; but, on the other hand, he found considerable layers of cortical substance, particularly round the roots. The greatest breadth of the main tubes was $\frac{1}{1000}$ P.M. In these teeth, although they were taken from young animals, the cavity of the pulp was almost closed. The continuations of the main tubes, which occupied the most internal and most recently formed part of the dental bone, were winding, only slightly parallel to each other, and very irregularly curved. On the other hand, the more

externally situated portions of the same tubes were faintly undulating, and ran parallel to each other, the interstices between them being of somewhat more than the width of a single tube. They gave off a great abundance of furcated branches at acute angles, stretched out in an external direction, as well as of other short, almost oppositely situated ones, which ran transversely over the interstices. Although a number of different, alternate layers of darker and whiter substances can be distinguished in these teeth with the naked eye, as well as with the aid of a glass, still Retzius could only perceive in a few places under the microscope definite parallel curvatures, or rings of osseous cells. The appearance of these rings seemed partly to depend on the more aggregated or scanty exit of small lateral branches from the main tubes. Immediately within the external surface of the tooth lay a beautiful layer of osseous cells, interwoven with incredibly minute and abundant bundles of the extreme terminal branches of the main tubes. In some places these extreme branches seemed to terminate in contiguous tubes and cells of the cortical substance. In the yellowish, osseous substance, which in the middle of the canine teeth had filled up that part of the cavity of the pulp which was prolonged towards the apex, a number of large cells were found, which, however, appeared to contain only very little osseous earth.

Trichecus Rosmarus.—Of the *walrus*, Retzius examined the canine and molar teeth. In both, the covering of enamel was wanting; but to make up for this, they were provided with a larger investment of cortical substance. The tubes bore the greatest similarity to those in the seal; they were of the same breadth, displayed the same degree of undulation, and the same relation to each other.

Their ramification, however, was much more distinctly evident. Both the long, bifurcated divisions of the tubes and the small lateral branches ran in acute angles towards the periphery of the tooth: a few only of the small lateral branches proceeded in short curves across the interstices and the most contiguous tubes.

In the singular teeth of this animal, the dental bone is particularly remarkable from the numerous, large, calcareous cells which, except at the extreme end of the alveolar part, lie scattered everywhere between the tubes. These calcareous cells appeared, nearer to the apex of the tooth, to be larger and oblong, and their length to be about $\frac{1}{50}$ P. M. Besides these, there was situated in the entire circumference of the teeth, between the extremities of the tubes in the dental bone, a thick, delicate, compact layer also of calcareous cells. The incisors of this animal are also remarkable from the more recent irregularly-formed, and almost preponderating dental substance, which constitutes a great part of the internal mass of the tooth, and, so to say, fills its cavity from the apex to the alveolar end, with the exception of a short space where it is hollow for the reception of the short pulp. To the naked eye, this substance seems clearer, and presents in its transverse sections a number of rings—of eyelets, as it were, as also various darker patches. This is the appearance which G. Cuvier has compared with that of pudding-stone, (*Leçons d'Anatomie Comparée*). This substance with which the interior is, so to say, stuffed, plays a very important part both in the canine and molar teeth, and is the cause why only the outer shell of the canine teeth of the walrus is applicable for finer bone-work. If an entire transverse section of a canine tooth of a walrus be examined, this spurious dental bone will be found to

occupy a third of its extent from before backwards, and half of its width from side to side. It fills up the greater part of the dental cavity, even in teeth which are not old. An incisor tooth, which Retzius examined shortly before publishing his work, was only hollow for the reception of the pulp for two inches and a half from the alveolar extremity. In this hollow portion are found a number of connected and generally cylindrical projections, resembling those of stalactites: of these the most central ones are the longest; the more external ones are shorter, and the most external are shortest of all. These projections leave between them a number of interstices which were filled with pulp, so that it would be more proper to say that the whole group of projections lie embedded in the pulp of the tooth. If we examine these remarkable contents of the incisor tooth of the walrus with the aid of the microscope, we shall find that their structure bears great similarity to the internal structure of the substance of some cylindric bones.

In a thin, transversely-cut, polished, and transparent section, it is found that every eyelet (of which the surface presents a number, from the size of a grain of mustard to that of a pea) represents, as it were, a peculiar dental corpuscule, with a hole in its centre, which is analogous to the cavity of the pulp, or to the medullary canal in a transversely-cut section of a cylindrical bone. These holes are in many places full of a yellowish or reddish matter, different from the dental substance, and which is probably nothing else than the dried residue of a thready pulp. From the border of these orifices tubes run in all directions, as in a small tooth, but inasmuch as they are immediately surrounded by other similar formations, they shortly become, as it were, pressed together. Hence

they cannot develope themselves equally in their entire circumference, but creep in bundles, forming beautiful parallel curvatures, between the contiguous substances. A great part of them proceed into the external, regularly-formed, dental bone, and are even continued into the main tubes which belong to it. These tubes of the dental bone, too, are abundantly and beautifully ramified, and present numerous concentric rings, which apparently owe their origin to parallel curvatures. In the lesser rings this arrangement is found to be less complete, and in the smallest there is often only a round, transparent spot, which now contains irregular scattered tubes, now congregated or isolated calcareous cells, &c. Calcareous cells are also scattered in almost every direction, and in great number, throughout this substance, as well between the more regular radiating bundles of tubes, as between the scattered ones, and they form everywhere frequent communications with the contiguous tubes.

Similar contents, but of less solidity, are found in the molar teeth, where they close up the cavity of the pulp as far as the extremity of the root, which has been remarked by G. Cuvier. This celebrated philosopher states that the teeth of the walrus are provided with enamel. His words are: " In some animals, for instance in the walrus, the enamel surrounds the tooth on all sides. In this animal the enamel is even thicker under the root of the molar teeth than on their crown." F. Cuvier speaks of only *one* substance in the tooth of the walrus: he says of the molars, " all these teeth have but one very short root, and they are entirely formed of one single substance, which is very hard, very compact, and analogous to that of the tusks."

That which G. Cuvier calls enamel in the walrus, is in

fact cortical substance, which is always much softer than enamel, and has indeed none of its peculiar properties. The cortical substance in the tooth of the walrus and in all other teeth contains calcareous cells and calcareous tubes, which, when viewed here in a transverse section, show themselves arranged in beautiful rings, one external to the other. In the canine teeth, the cortical substance forms only a thin layer of from $\frac{1}{2}'''$ to $1'''$ in diameter; but in many parts of the small molar tooth the diameter is $2'''$. It surrounds the tooth on all sides, except at the masticating surface which has been worn away, where the dental bone itself is exposed. It is this thick cortical investment which gives to the molars of the walrus their peculiar clumsy appearance, and causes them to lose, as it were, their normal shape. If such a tooth be split along its axis, that part which is formed by the pulp is found to be deeply bedded in the above-mentioned shapeless cortical mass, which, as has been said, surrounds the root itself. The tooth whilst whole is thicker towards the crown than towards the root; but on its being sawn open, it is found that the dental bone, properly so called, is narrower towards the crown and thicker near the root. There is a well-defined boundary between the dental bone and the cortical substance, in the shape of a clear, yellowish streak: nevertheless, it is found by means of the microscope that the outer extremities of the tubes, or the outer cells in the dental bone, communicate with the internal cells of the cortical substance. These communications are particularly distinct in the root. Besides them, there were also found here tolerably large tubes, which run upwards into the substance in the centre of the tooth above described, and which contained a red matter, probably dried blood. These broader tubes are very similar

to the medullary canals in deer-horns which have been shed. Retzius presumes that they are here the small and scattered remains of the cavity of the pulp, since it is very evident that the closing of the cavity of the pulp in the walrus is connected with a division of the pulp itself, which seems to be separated into a number of long threads, and round these the above-described, small, dental corpuscules, constituting the central substance, begin to form in the shape of projections, which, when they are cut transversely, are found to have a central cavity from which main tubes radiate in all directions.

The *cortical substance* in the *walrus* invests the canine as well as the molar teeth, and is deposited in such immense quantity round the latter, that the small teeth lose through it their proper form, as has been above described. The internal structure of this substance is remarkable, from the abundance of almost parallel, ramifying, thick-set tubes which it presents, and between which the cells lie scattered. These tubes run, too, perpendicularly, so to say, towards the surface of the dental bone, and seem, as it were, to commence and terminate in the different layers in which this substance was formed. They are, however, by far less regular and parallel than the tubes in the dental bone. Besides the cells themselves, the interstices are also filled in a great measure by a net-work of minute tubes. The tubes which enter the cells form thick bundles round them, which seem to be largest on the external side of the cells. In longitudinally-cut slices the cells were of the form of an almond: they were about $\frac{1}{200}$ line P. M. in length, and about half that in width. The tubes of the cortical substance entered into numerous connexions with the finer terminations of the tubes of the dental bone, particularly

at the end of the roots of the molar teeth : at the same place were seen a number of larger canals which entered into the cavity of the pulp, and probably belonged to blood-vessels.

Delphinis Delphis.—The teeth of the *dolphin* have a covering of enamel on that part which projects from the alveolus, and of cortical substance on that which the alveolus embraces. The cavity of the pulp was so filled with dental bone as to be reduced to a small canal, which was only present in that fourth of the length of the tooth nearest the root. This remaining portion of the cavity of the pulp was of little more than the thickness of a human hair, although the tooth examined was that of a young animal. In some teeth it was somewhat wider, but closed at both extremities : in others, it was altogether closed in its entire length.

The tubes in the dental bone of this animal are somewhat smaller in their widest parts than those of the *phoca* and *tricheclius.* The interstices were from three to four times broader than the diameter of a single tube. In the three-fourths of the tooth nearest the crown, they were parallel to each other ; but in the fourth, nearest the root, they were almost irregularly winding. Some of the main tubes were extremely faintly undulating, in lengthy waves ; others were not. In the coronal half of the tooth seen from both sides, they lay like S's placed against each other, with their upper ends converging towards the crown ; but nearer the root they were almost straight and transverse ; and more inferiorly still, in the root itself, their direction was the same as in the crown. Owing to their minuteness, and to the comparatively large interstices between them, the division of the main tubes, as also the giving off of the lateral branches, were seen with particu-

lar distinctness. The former is best seen nearer the root, inasmuch as at every division of the main tube the new branches curve somewhat away from each other, whilst those in the part nearer the crown part straighter and at more acute angles.

The small lateral branches run in the greatest abundance from both sides of the main tubes and their divisions, generally in transverse arches, of which a part cross over the nearest tubes and interstices beyond. The outer extremities of the main tubes are distributed in bundles into the surface of the dental bone, next to the enamel and cortical substance, in extreme minuteness and abundance, and also into the thick layer which is there situated, of minute, angular, calcareous cells. Such cells were found almost everywhere in the dental bone of the dolphin. In the teeth which Retzius examined were found, immediately within the external surface of the dental bone, several white streaks, which were present in the entire circumference of the tooth, and which were entirely formed by such closer, partly very large and angular calcareous cells, some of which ran into each other, whilst others were in communication with the minute extremities of the tubes.

Round the medullary canal there were here, as well as in many of the above-described teeth, oval tracts where the main tubes had been supplanted by peculiar and, as it were, more independent tubular structures. The main tubes round about these clear, oval tracts surrounded them in curves, and gave off thinly scattered branches which wound amongst them from all sides: a part of the tubes were at their terminations, as it were, pyriformally dilated into calcareous cells, which by intermediate tubes again communicated with other cells of triangular and

various other forms. The tubes themselves formed here also numerous and direct communications with each other, in the form of loops, net-work, &c., (Plate A. 3. Fig. 4). On some of the larger cells Retzius counted from eight to ten larger tubes, which were given off from them, or opened into them. In the teeth, of which the roots were pointed, the cells were so predominant that scarcely any regular tubes were found; but nevertheless a definite border was observable between the dental bone thus constituted and the cortical substance, in which the cells lay in nearly regular rows. The external cells in the dental bone formed, however, connexions with the cells in the cortical substance.

The teeth of the dolphin, like those of the walrus and seal, appear to be closed at an early period, and to be deprived, as it were, of their pulp, which peculiarity may perhaps have its origin in the circumstance that the teeth of this animal have generally only to work on soft substances, are hence less exposed to be worn away, and so have less occasion for additional growth than those of most of the land mammalia. On the other hand, they appear to be provided better than other teeth with a strong covering of cortical substance, secreted by the internal membrane of the alveolus, which is doubtless a residue of the dental sac. If we suppose that the tooth must keep up a continual communication with the rest of the organism, it is probable that when this ceases to be kept up by means of the pulp, from the disappearance of the latter, it is effected through the cortical substance, and the tubes which pass from it into the cells of the dental bone: moreover, such an alteration may in some measure promote the extrusion of the tooth from the alveolus after the cavity of the pulp has closed.

In an old tooth of the dolphin, Retzius found *cortical substance* only in that part which is wedged into the alveolus, and there only in a rather thin layer. It displayed here also a great abundance of similar, almost parallel tubes, running from without to the surface of the dental bone, between which the cells were situated. The latter were for the most part drawn out into irregular shapes: some were very large; but most were oval and round. The round ones were of the size of $\frac{1}{300}$ line P.M.; the oval ones $\frac{1}{250}$ line broad, and double as long. They lay in beautiful rows, running towards the periphery of the tooth, and the tubes opened into them in almost equal quantities at every angle.

Crocodilus Sclerops and *Esox Lucius.*—The teeth of the *crocodile* and of the *pike* have a covering of enamel on the crown, and a tolerably thick coat of cortical substance on that part which is situated within the alveolus. The breadth of the largest tubes of the dental bone is $\frac{1}{1000}'''$ P.M. They are in lengthy curves, are considerably apart, and faintly undulating. In several places they present parallel curves; but still run without definite arched curves, and (when slightly magnified) seem to course almost straight from the internal cavity to the external surface of the tooth. Their distance from each other was equal to the breadth of four or five of them. The trunks of the tubes divide distinctly immediately after their commencement at the internal cavity: the branches of the divisions curve immediately away from each other, and wind particularly in the neighbourhood of the root nearly irregularly. Numerous minute branches of various lengths are given off on all sides, of which, however, most seem to turn towards the root. These ramusculi seem in many places to terminate with dilated extremities in osseous cells. Nume-

rous layers of osseous cells are found in the whole length of the tooth, some of which are of larger size than others. They curve beautifully round in the crown, and follow most exactly the contour of the dental cavity. The largest layer of these cells is situated here, as in the teeth of most mammalia, in the external layer of the dental bone. It is partly these layers of osseous cells and partly parallel curvatures which form the numerous, delicate, parallel streaks which, under a simple magnifying glass, are visible in the transverse sections of the teeth of the crocodile. The inner side of the dental bone, or its cavity, appeared to be lined with a thin membrane, which protected it from contact with the reserve teeth, which this cavity also contains.

In the crocodile also the *cortical substance* only coated the roots. Its cells were about $\frac{1}{300}$ line P. M. broad, and for the most part circular and stellated, every stellated point being constituted by the entrance of a tube into a cell. The tubes scattered in every direction were so minute, and formed such dark groups, that they could not be very evidently distinguished. Still Retzius could see that they did not run so parallel or regular as in the cortical substance of the animals whose teeth have been last described.

Python Bivittatus.—In the teeth of the *python* Retzius could discover neither *enamel* nor *cortical substance* : the tubes of the dental bone are a little thicker than in the crocodile, and have an extremely faint curvature externally and towards the root. Only in a few places, and after longer intervals, do they present a slight curve. Their distance from each other appears to be equal to the width of four or five of them. They do not divide, as in the above described, into branches, which in their

turn are trunks; all branches in the crown of the tooth run outwards towards the periphery; and in the remaining part they are given off by that side of the main tubes which is nearest the root. These branches are given off almost parallel, and at very acute angles. Some of them are thicker than others, and they correspond to the main divisions in other teeth. They also give off numerous branches, which, however, run parallel with the others. This parallelism gives to the dental bone of the python, seen through the microscope, a very peculiar appearance (Plate A. 3. Fig. 6). In the surface alone appeared a faint trace of osseous cells.

Sparus Rondeletii and *Balistes Vetula.*—In the limited number of fish-teeth, examined by Retzius, he found the dental bone of the *sparus rondeletii* and *balistes vetula* to resemble most in point of internal structure that of the mammalia and amphibia, inasmuch as in these fish it is white and hard like ivory, and displays, when viewed under the microscope, beautiful, regular, minute, and parallel main tubes.

In the *Sparus Rondeletii* the diameter of the tubes in the incisor teeth, near their commencement, is $\frac{2}{3000}'''$ P. M. They are tolerably regular and closely undulating, with several larger and smaller parallel curvatures. Internally towards the cavity of the pulp in the crown, they were very and irregularly winding. They divide at acute angles, and the branches lie so close to the trunks from which they have been given off, that their divisions are scarcely visible, with the exception of those which rise nearest their outer extremities, in the neighbourhood of the external surface of the tooth. The osseous cells were very indistinct. The coating of enamel was thick, light brownish, and traversed by innumerable minute furrows, running

in an external direction, partly crossing each other, and nearly resembling tubes.

In the *Balistes Vetula*, the tubes are more minute than in the sparus, being $\frac{1}{1000}'''$ P. M. broad: they are beautifully parallel, with the exception of their more recent parts in the coronal end of the cavity of the pulp. Their undulations were very faint, and very lengthy. Their distance from each other was scarcely equal to the breadth of a single tube. The larger branches lie close to the trunks, whilst the smaller ones, for the most part, curve away from them in a transverse direction. Near the surface of the tooth the ends of the main tubes themselves presented considerable parallel curvatures.

The greater part of the tooth of this animal is covered by a thick, hard and strong enamel, which looks, in many places, as if the tubes of the dental bone were continued into it, and which, like that of the sparus, is full of furrows, coursing in an external direction. Round the root-end of the tooth there appeared to be also a sort of cortical substance.

The rest of the fish-teeth which Retzius examined, consisted, for the most part, of a more imperfect dental bone, with a number of larger tubes forming rude anastomoses, and nearly resembling the soft imperfectly developed dental bone, which fills up the interior of the teeth of the bradypus.

The cells in the above-mentioned *cortical substance* were large, extremely irregular, terminating immediately in each other, or being, as it were, confounded together. The course of the minute bundles of tubes was also in the highest degree irregular. The cortical covering was very thin, and terminated immediately under the border of the enamel.

In the other fish-teeth which Retzius examined, he found no other substance which could be considered as analogous to the cortical covering, except the proper osseous substance, which united the tooth with the jaw. In the *Shark*, whose teeth are bound to the jaw by ligaments, this substance formed a rounded basilary part on the free extremity, the organization of which part is scarcely to be distinguished from that of the more perfect structure of real bone.

Squalus cornubicus.—In the *lamna* most of the teeth, though flat, were still somewhat hollow, and were provided with a thick coating of enamel. The largest diameter of the tubes of the dental bone is $\frac{7}{2000}'''$ P. M. At the top of the tooth they run in an upward direction; on the sides, transversely towards the external surface; and nearer the root, (which is fastened on a basis of real bone), they radiate in a downward direction. The proper trunks of the tubes lie at a tolerable distance from each other, and their divisions, which in many cases commence very near to the origin of the main tubes from the internal wall which is turned towards the cavity of the pulp, recede considerably from each other—(Plate A. 2. Fig. 3); whilst their diameter diminishes more rapidly than in more perfect teeth of the same size. In the entire course of the divisions, as well as of the trunks, numerous minuter lateral branches are given off in a direction which is exactly transverse to that of the tubes from which they rise. In the neighbourhood of the external surface, these minuter branches become completely parallel, and terminate under the enamel in large, irregular calcareous cells. These calcareous cells give off other irregular tubes, which partly unite with each other, and partly terminate in other

cells. The outer part of the dental bone forms, as it were, a peculiar layer, which is darker than the internal one; precisely at the border between these two layers are situated a number of large calcareous cells. Besides these, other calcareous cells of different sizes are found throughout the dental bone. The cavity of the pulp in most of the teeth of the shark, which Retzius examined, though they were in different stages of developement, was very small. Towards the root some larger tubes opened into it, which contained a red matter, bearing some resemblance to desiccated blood. These tubes ran longitudinally into the osseous basis on which the root is fastened, and terminated in its medullary canals.

Esox Lucius.—In the *common pike*, as in most fishes, are found a number of unequally developed teeth—from the smallest loose points, to the teeth immovably fixed to the jaw by a solid osseous base. On none of them could Retzius, by means of the microscope, perceive any covering of enamel: on the contrary, the dental bone was found to be so soft, that it could almost as easily be cut with a knife as a common quill. In the neighbourhood of the apex only, and on the sharp edges, did it feel somewhat harder at the surface. The bone by which the older teeth were fastened by their base to the maxilla, constitutes, though of a different appearance, a continuation of the inner or more recent dental bone itself, and wants the whiteness and lustre of the remaining tooth, inasmuch as it is traversed by large tubes even to the surface. The dental bone itself in the pike is properly divided, as it seems to Retzius, into an internal kernel provided with large tubes, and into an external thinner part, which latter forms the covering of the first, and contains minute and parallel

tubes. The larger main tubes which occupy the internal more imperfect part of the dental bone, are in their widest parts about $\frac{1}{85}''$ P. M. in diameter. They run almost parallel with each other, and with the axis of the tooth, and form with each other numerous larger and smaller anastomoses.

Near the base of the firmly-fixed teeth, the larger transverse anastomoses are so near to each other, that the interstices are scarcely as wide as the diameter of the larger tubes. In some few recent teeth these tubes contained here and there a blood-red substance, and may hence be regarded as divisions of a cavity of the pulp. Remarkably beautiful and very short tubes of $\frac{1}{500}$ to $\frac{1}{1000}$ P. M. in breadth, are given off from the large main trunks, generally in a transverse direction: most divide immediately after their origin into extremely minute bundles, of which the ramifications enter into innumerable reticular communications with each other, filling up also the interstices between the larger tubes. In the passage from this internal dental substance with large tubes to the outer one in which the tubes are minute, a particular simple extension of the tubular structure is observable, formed by the anastomoses of the terminations of the main tubes, which are straight at their extremities, but arched previously, and which constitute, as it were, the boundary between the external and internal dental substance. From these larger border-tubes are given off more minute, short, tubular trunks, which follow nearly the direction from the above-mentioned boundary outwards, as the small tubes in the more recent, thin-walled, hollow shells of the crown in more perfect teeth, which run from their large cavity of the pulp externally towards the surface. Here too those which are next to the apex run almost parallel

with the axis of the tooth; but those which are nearest the root transversely to it, and so on. They divide at their commencement into bundles of larger and smaller branches, which enter into numerous reticular anastomoses with each other, but which most externally give off very beautiful, close, parallel, generally straight tubes of about from $\frac{1}{1500}$ to $\frac{1}{2000}$ P. M. in breadth: amongst the latter Retzius could discover neither branches, anastomoses, nor cells. This most external stratum of dental bone gives to the transverse sections of the tooth of the pike a peculiar and pretty appearance, and resembles, slightly magnified, a layer of enamel. It begins with an acutely angular attenuated border, near to the base of the tooth, where the basilary part of the dental bone terminates, which, in recent teeth, is of a grayish, in dried of a yellowish colour; it increases somewhat in thickness nearer the apex, in which the minute tubular ramifications form, as it were, with the main trunks, the most beautiful dendritic figures. This minutely tubular, external portion of the dental substance is of the purest white, and is also much harder and more compact than the interior of the dental bone. To judge by the hardness of its surface in dried teeth, Retzius would have concluded that it was invested with an extremely thin membrane of enamel; but he could not detect any with the microscope, although accurate authors have asserted that it is present on the teeth of the shark.

Gadus Molva.—In the *ling* the fixed teeth sit like epiphyses on small processes, formed by a peculiarly modified dental substance, which presents, as it were, a transition from the osseous substance of the maxilla to that of the tooth. The teeth themselves are short, conical, and half transparent, and have at their apices

alone, when those are not worn away, a coating of enamel. This latter is here placed like the iron projection (*jernskoningen*) on some wooden spades, runs before and behind as into a transverse edge, and in some into a short lancet-formed point: it gives to the apex of the tooth its white appearance, and is found, it seems, on all teeth from their commencement. The fixed teeth also have a cavity of the pulp, which in some is larger, in others smaller, and which unites with a corresponding excavation in the osseous base on which the tooth is fixed.

In some teeth the cavity of the pulp is very small, being nearly reduced to a conical tube running in the direction of the axis of the tooth.

In the dental bone itself of the *ling* there was a great paucity of tubes. Along the wall of the cavity of the pulp, which ran longitudinally, and was in part tubiform, the main tubes opened with short trunks of from $\frac{1}{50}$ to $\frac{1}{70}'''$ P.M. in thickness, which ran towards the apex, and in an outward direction, (*rami patentes, Botanic:*) and gave off branches on both sides, between which there were considerable intervals: these branches formed, with others of the contiguous tubes, large loop-formed anastomoses, and their outer extremities entered also into closed anastomoses, almost like the more minute blood-vessels in the villi of the abdominal canal. This most external arrangement of anastomoses forms here, as in the pike, a sort of boundary, beyond which no larger tubes are found.

The more minute lateral branches of the tubes of the dental bone in the ling were not easily discovered; they appeared to be less regular, and generally ran in a direction transverse to the tubes from which they rose, or parallel to the axis of the tooth.

Anarrhichas Lupus.—The teeth of the *wolf fish* resem-

bled in many respects very much the solid teeth of the ling. Like these they contain a small cavity; like them they are placed as epiphyses on elevations of the maxilla; they have all only a small patch of enamel on the apex, and their tubular structure is almost the same, with the exception of the difference which arises from the more limited extent of the cavity of the pulp. The processes on which the teeth are fastened have particularly attracted the attention of Cuvier. In his lectures on comparative anatomy, he says of the anarrhichas, " Its jaws are covered with elevations which are composed of fibres or tubes alone. . . . . In the full-grown animal nothing is found besides these, and one feels inclined to regard them as teeth. . . . The sea-wolf is the only animal with which I am acquainted in which, besides the teeth, a part also of the bone (viz. the osseous elevations of which I have spoken above) falls out. The shedding of these is conformable, as I have already mentioned, with the shedding of the horns of deer; and their separation is doubtless effected in the same manner, with this only difference, that the new elevation on which the tooth is fixed does not take precisely the place of the former one, but is developed by the side of it, and only through its enlargement does the hollow left by the falling out of the old one become filled up."

Retzius has examined several heads of the anarrhichas, and, from what he has found, cannot but conclude that the views of Cuvier on this point are completely false. The processes described on which the teeth are said to be situated do not, he says, exist in reality. Their appearance is a mere deception, which originates in the following manner:—At a little distance from the place where the teeth are fixed, runs a border which resembles the border

of the alveolus. The osseous substance which lies between it and the teeth, is peculiarly porous, and has on both sides small furrows which correspond to the interstices of the teeth, and which give to this basilary substance, as it may be called, an appearance as if it were divided into as many processes as there are teeth fixed upon it. This appearance is also strengthened by the circumstance, that at the end of each of the above-mentioned furrows, next to the boundary of the dentigerous bone which resembles the border of the alveolus, the round orifices of small cavities are found, which contain sacks for the reserve-teeth, and some of them also reserve-teeth themselves nearly fully developed. These alveolar orifices, of which one is situated near the end of each interdental furrow, and consequently before each dental interstice, chiefly contribute to give an appearance to the above-mentioned basilary part of the dentigerous bone, as if it were divided into as many processes as there are teeth.

Whence Cuvier derived the idea that these portions of bone supplied the place of the teeth after the latter had been shed, and that they themselves are finally changed—this, says Retzius, I am not at all able to explain, for in the numerous heads of the anarrhichas which I have examined, I never found any teeth wanting, though I have seen them very much worn away. The longest and most anterior teeth in the inter-maxillary bones, and those which correspond to them in the inferior maxilla, have most the appearance of being situated on peculiar osseous processes, which, in connexion with their teeth, have a distant resemblance to the place where the horns of the deer are fastened on the bone beneath, and this similarity has been noticed both by Cuvier and Von Born. The latter has given a faithful drawing of the beautiful circle of folds, which is seen on the spot where the tooth

is situated, after the latter has been removed. (See Heusinger, Zeitschr. f. d. organ. Physik, Bd. 1. Taf. vi. fig. 2.) The same author incorrectly asserts that the teeth of both the anarrhichas and the pike are invested with enamel; whilst Andre on the other hand says, (Phil. Trans. of the Royal Society, vol. lxxiv. p. 277,) "The teeth are formed of a hard bony matter, not covered with enamel as in some animals." Retzius has never found a trace of enamel on any protruded tooth of the anarrhichas, which had grown fast at its base. Having, however, always without exception seen the teeth of this animal worn away at the apex, he examined the small dental germs enclosed in the above-mentioned reserve-alveoli, and found that all these had at their apex, or at the point which corresponded to it, a small portion of enamel. The germs of the conical, pointed, front teeth had only the extreme summit coated with enamel; the lenticular germs of the obtuse teeth in the vomer had in the centre of their almost flat and radiated coronal surface a small white elevation of enamel, of which the breadth at the base was not quite $\frac{1}{3}'''$ P. M. That a fish which uses its teeth for crushing large muscles, snails, lobsters, &c., must soon wear off these small tips of enamel, and that the latter indeed can scarcely be of any use here, seems to be quite evident.

The main tubes in the dental bone are somewhat larger than in the ling; the inner ones run parallel with the axis of the tooth; the external ones incline somewhat outwards. This direction of the main tubes in the anarrhichas has its origin in the circumstance that the formation of the tooth is in a great measure finished before the cavity of the pulp has begun to be formed, as may be learnt from the dental germs; hence the cavity of the pulp does not attain, as in the ling, the extended form of a main tube, from the sides of which the other tubes rise. These main

tubes subsequently divide into beautiful, parallel, minuter branches, which form numerous reticular anastomoses with each other, and which partly occupy the interstices: they terminate externally in the same way as in the ling.

The larger trunks of these tubes were in a great measure filled with a red matter, which was doubtless a production of the pulp. The more minute calcigerous tubes were very indistinct.

Cyprinus Idus.—In the *carp*, which has only teeth in its pharynx, the structure of these organs is very similar to that in the balistes. They contain a considerable cavity of the pulp, which extends through almost the entire length of the tooth, and partly also laterally into the bone beneath the fastening of the tooth, where there is an orifice for the entrance of vessels from within. When these teeth are viewed with the naked eye, and also with the lens, their points are seen to be tipped with a white, transparent substance, resembling enamel, but Retzius could not render himself certain that it was such by the aid of the microscope. The tubes of the dental bone are tolerably regular and parallel; their thickness near their commencement at the cavity of the pulp is $\frac{2}{3000}'''$ P. M. They bifurcate, and the divisions run parallel with each other; but the more minute branches, particularly those towards the outer part of the tooth, diverge more, and run, as in the balistes, in a direction towards the base of the tooth. Hence the branches are most beautiful, most abundant, and most distinct towards the external part of the tooth.

Cuvier, as well as Von Born, was acquainted with the tubular structure in different fish-teeth; but both seem to have considered the tubes, or fibres as they call them, as undivided, and as running parallel from the cavity of the pulp to the end of the dental bone. Von Born says, ex-

pressly, that some fish-teeth consist of fibrous substance with a coating of enamel, others of osseous substance with the same. In the former class, he places the teeth of the anarrhichas, in which the tubes have a considerable diameter, so that they may easily be seen when slightly magnified: in the latter class he numbers such teeth as have a harder and more compact dental bone, in which the tubes escaped his view. Both Cuvier and Von Born maintain that nerves and nutritive vessels enter the hollow tubes. Retzius has found that the larger of these in the shark, pike, ling, and anarrhichas, often contain a red substance quite similar to the pulp, in the same way as do the larger tubes in the inner mass of the tooth of the walrus, (whence they may rightly be pronounced to be ramifying prolongations of the cavity of the pulp, analogous to the proper medullary canals in the *substantia ossea*,) and believes that the more minute tubes are alone properly calcigerous.

"These inquiries into the Microscopical Structure of the Teeth," says Retzius, in conclusion, "have been made with the greatest care, and have cost me a great deal of trouble: they refute the observations and views of many of my predecessors; but I nevertheless clearly see, that the results to which I have arrived can make no pretensions to completeness. Whoever considers, for an instant, the variety of forms presented by the teeth of mammalia, amphibia, and fishes, as also their diversity corresponding to the diversity of the parts to which they are fixed, and, further, the different milk-teeth and permanent teeth, must instantly see that a complete investi-

gation of this department of science would be a labour of several years, and would fill a large volume. I confess, too, that my observations can make no pretensions to infallibility, which can only be attained in proportion as experiments are made with exactness and repeatedly varied. According to my experience, it is by varying experiments continually, that light is most easily thrown upon obscure phenomena. Hence, as long as I confined my observations to the teeth of the human subject, I overlooked the osseous cells which are so important towards obtaining a knowledge of the dental bone; the divisions of the tubes also escaped me for a long time, as did also their highly interesting ramifications, &c. I cannot therefore regard the present communication as anything more than a foundation for future inquiries, and I submit it to the eye of the public, in order that it may be strictly examined and brought to perfection. I have found the subject so important, and its examination has given me so much satisfaction, that I ardently hope to find a future opportunity to correct a portion of the defects which I have already discovered. In the mean time some general results may be drawn from the facts which I have related, and the comparison of them with observations on similar structures. These results are as follows:—

"The teeth of mammalia consist in general of three substances, the dental bone, the enamel, and the cortical substance. These three substances form also the teeth in certain amphibia and fishes. The dental bone contains tubes and cells which are in communication with each other, and which are analogous to the minute tubes and cells forming an important part of the organisation of bone.

"The minute tubes in the osseous substance I demon-

strated, together with those of the dental bone, by making slices of teeth which were still fixed in the alveoli. Preparations made in this manner contained of course a portion of the alveolar bone, which, when it was filed as thin as the sections of the tooth, illustrated the internal structure of the dental bone. These tubes in bone itself had been shortly before found by Müller and Miescher, as also by Purkinje and Valentin. Müller was the first who showed that they contained calcareous matter. They are still more minute in bone than in the tooth, and are many times smaller than the most minute blood-vessels, their thickness, according to Müller, being $\frac{1}{5000}$ line P. M. (*J. Mulleri Observationes de canaliculis corpusculorum ossium, atque de modo quo terrea materia in ossibus continetur.*) They radiate from the minute medullary canals, which were first more carefully examined by Purkinje, give off an abundance of branches which form reticular communications, and terminate in Purkinje's corpuscula, or cells. I call them by the latter name, because I am convinced that they are excavations in the substance of cartilage as well as in that of bone, which partly contain a clear fluid, and partly deposits of calcareous salts. The horns of deer are organised in nearly the same manner, with this difference only, that in them the minute medullary threads appear to be really blood-vessels, which view is most strongly confirmed by Berthold in his work, "*Ueber das Wachsthum, den Ab-*" "*fall, und die Wiedererzeugung der Hirschgeweihe, in dessen*" "*Beiträgen zur Anatomie, &c.*" *Göttingen*, 1831.

"The tubes in the dental bone open into the cavitas pulpæ, and give off branches in their course, which form a network of communication between each other, and which terminate in cells. These cells, together with the branches from the main tubes, nearly fill up the inter-

stices between the latter. The breadth of the main tubes varies from $\frac{1}{400}$ to $\frac{1}{1000}$ of a line, P. M., and diminishes as they divide into branches: the most minute subdivisions are many times smaller than $\frac{1}{1000}$ of a P. line. It is very likely that the tubes and cells which are seen under the microscope form but a small portion of those which really exist.

"The dental bone, as Cuvier and several others have described, is deposited layer by layer round the surface of the pulp, and the most external layer is that which is first deposited. During this process the most external closely contiguous cells have their origin, and also the peripheral extremities of the main tubes. During the formation of successive layers, the latter are also continued inwards; and it would seem as if their parallel curvatures were produced during their continuation from one layer into another. In this case we have grounds for presuming that there is a periodical motion of the pulp, by means of which the tubes, whilst in process of formation, are at one time pushed towards the apex of the tooth, and at another drawn down and in the direction of its root. We may also imagine the periodical motion to be of various kinds. The most delicate and most numerous undulating curvatures must be the work of very short periods. The longer, shallower curves, of which every fully developed tube presents only a few, may be regarded as marks of other and slower periodical changes in the formation of the pulp, during which those producing the short tubular undulations are carried on uninterruptedly.

"These processes, however, are only carried on with complete regularity before the tooth protrudes through the gums. In the extremities of the roots, and in the osseous mass filling up the centre of the cavitas pulpæ, which are subsequently formed, the tubes are less regular and uni-

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form than in other parts. In this last formed osseous mass, the branches of the tubes are best shown, because both the former and the latter have no longer their parallel arrangement. In this irregular form of dental bone the largest cells are found, and the entrance of the tubes into the latter is admirably well seen, as also the reticular meshes formed by the tubes themselves. In many places this substance presents so great a similarity to other osseous formations, that it appears rather to belong to ordinary bone than to dental bone; it differs, however, from the former in the larger size of its main tubes.

"In many animals the pulp is divided after the outer shell of the dental bone has been formed (*e. g.* in the bradypus, trichechus, esox, gadus, anarrhichas, &c.) After this has taken place, particular layers are formed round the division of the pulp. The osseous substance which thus arises has a still greater similarity to ordinary osseous structure. The divisions of the pulp prolonged into fibres then show the strongest similarity to the medullary fibres in bones, and form in many cases, like the latter, lateral communications, (for instance, in the pristis, gadus, anarrhichas, &c.) In several animals, particularly in the trichechus, this form of dental bone presents the most evident similarity to proper bone. There are found in it medullary tubes, (canals of the pulp,) and medullary fibres, (fibres of the pulp,) round which groups of concentric layers have formed; from these the minute tubes radiate, which in the different layers are as it were pieced together, and in these layers concentric rows or rings of cells are again found just as in bones.

"The similarity between dental bone and real bone is hence greater than one is inclined to believe after making the first microscopical researches. The greatest difference

between them consists, as I believe, in the manner of their formation. In dental bone the most external layer is first formed, in bone it is last formed, round each small medullary fibre.

"In bone every medullary fibre has the same size at its commencement which it afterwards retains. The small osseous cylinders, or layers, are formed by the veins, which lie externally round the medullary fibres, or out of the mass plentifully supplied with veins, in which the scattered, so called osseous fibres lie embedded. In order that the hollow fibrous structure in bones may be connected, the individual fibres and the small medullary canals enclosed within them form numerous communications, which give to a bone, during the process of formation, its well-known reticular appearance. Hence the medullary organ in the osseous fibres is not, in my opinion, like the pulpa dentis, the formative organ in bone; but, on the other hand, it is probably of so much the greater importance for the preservation of the bone. The pulpa dentis, however, is the organ of formation as well as of preservation in the dental bone. In this diversity may probably have its origin the great difference between bone and the tooth, that the substance of the former is subject to 'resorption' and considerable change, which is not the case in the latter. The horns of deer remain for a considerable time without additional growth, and without 'resorption.' It is well known that they are only shed in those animals in which the organs of propagation are uninjured; in castrated deer the growth goes uniformly forwards.

"Many of the cylindrical bones are surrounded externally by concentric rings, which encircle the whole in the same manner as the regular, external, dental bone in

the walrus surrounds the substance which is similar to pudding-stone. It might hence be said that a tooth with a simple pulp is analogous to an osseous fibre from the interior of bone, or to the most external, concentric layers of a bone which surround the whole.

"It can scarcely be doubted that the minute tubes in dental bone, in the cortical substance, in common bone, and in the horns of deer, as well as the cells which are united with them, are a peculiar kind of vessels, containing a nourishing and supporting fluid, of which probably the composition differs at different periods. This fluid is most likely secreted by the capillary vessels which clothe the surface of the pulp. In common bone in which the minute tubes open into the medullary canals, this secretion probably takes place after the hollow osseous fibres have been formed, in a great part from the surface of the medullary fibres enclosed in the cavity of the osseous fibres, whilst the minute tubes collect round them in a radiating manner.

"In the horns of deer, in which the blood-vessels occupy in a great measure the place of the medullary fibres and of the minute medullary tubes, the same minute osseous vessels are seen radiating from the parietes of the minute canals which contain these blood-vessels.

"That the small osseous tubes and cells contain osseous earth is seen from their whiteness, which disappears when the preparation is laid in diluted muriatic acid, in which afterwards the calcareous salts are precipitated, the previously white and dark osseous tubes and cells being rendered quite colourless and clear, after having been submitted to the action of the acid. These calcareous salts were probably left behind in the tubes from the first formation of the dental bone, and deposited them-

selves round the parietes of the tubes and cells. In common bone, probably, the peculiar vessels in question take a part in the continual, or apparently continual, exchange of substance: this cannot in the same degree be the case in dental bone, inasmuch as in this no such exchange appears to take place. What end then is served by this beautiful organisation of the dental bone? We have many examples that nature organises structures which have a close affinity to each other according to one and the same plan, and hence we have, in different parts or organisms, formations, which in some are of the greatest importance, whilst in others they are of much less functional significance, or of none whatever. If we hence assume, what is highly probable, that in bone the peculiar vessels in question give passage to fluids during the entire life of the animal (or a great part of it) —which fluids contain the solid as well as the liquid materials of the osseous substance—it does not necessarily follow, that the same process must be carried on in the teeth during the whole of life. On the contrary, I am inclined to believe that these vessels in dental bone are at their height during the first period of the formation of the tooth, and exercise then their more perfect action. At the same time, the existence of a continual vital process in the tooth as well as in the crystalline lens cannot be denied, which, however, appears to be carried on without any constant exchange of solid matter, and must hence consist in a renovating circulation of the dental fluids. I refer here to an observation of G. H. Weber, published several years ago, and before the existence of the peculiar vessels in question was suspected:—"The tooth appears "then to be penetrated by fluids secreted by the dental "germ, and by the membrane surrounding the root ex-

"ternally, (both of which are abundantly supplied with "vessels.) These fluids, without circulating in organic "canals, may operate much towards the preservation of the "tooth, as also towards the decay of the dental substance "when their composition is morbid."

"When milk-teeth are examined just before they are about to be shed, they are found to present an appearance as if, from pressure of their permanent successors, they had wasted or been absorbed at the root. The crown of the advancing tooth appears to have pressed itself into the extremity of the deciduous one. I have carefully examined how this appearance is produced, and have come to the decided conviction that neither tabescence, absorption, nor erosion, has anything to do with it.

"In the milk-teeth which presented it, I found the radical extremity quite entire, as also the small cavitas pulpæ and the deep enamel furrows which, in the horse, descend from the crown, and are filled with cortical substance. I found moreover, on making transverse sections of them, that their roots assumed a form corresponding to that of the crown of the advancing tooth, by growing round and closely shutting in the latter.

"In the teeth a greater degree of hardness is required than in any other part of the organism, and a hardness moreover combined with the same tenacity which exists in bone. They are destined to be subject to almost constant pressure; and that property in which they differ from bone, of not disappearing under or being affected by pressure, must hence be a necessary condition for the fulfilment of their function. This property, which is only found besides in the corneous structures of the skin, is owing, in the teeth, to the circumstance that the solid parts once formed are not changed, but are con-

stantly preserved by the circulation of a fluid in their minute tubes and cells.

"The enamel presents a much more simple structure, being without sanguiferous or any especial vessels: its structure most resembles that of the crystalline lens. It also probably requires an organic fluid for its preservation, which, as I presume, is conducted to it by the tubes of the dental bone, permeating afterwards the membranous parietes which probably clothe the individual fibres. This substance is not found in all teeth, but appears in many cases in a rudimentary state, so to say, inasmuch as it is missed in the teeth which have not yet or have only just protruded — as in the anarrhichas lupus, gadus molva, and phoca annellata. Though I found no enamel on the teeth of the trichechus rosmarus, I still presume that a trace of it may be discovered on the crowns before they have been worn away. (In the halychærus griseus a complete though thin covering of enamel is found.)

"In some animals the enamel is formed not only within the folliculus dentis, but is also secreted during the whole of life by a small ring-like organ, which, near the bottom of the alveolus, surrounds the root of the tooth (in the hare, beaver, &c.)

"The cortical substance is found on the teeth of most mammalia, and is also met with on those of amphibia and fishes. It is everywhere distinguished by a predominant abundance of osseous cells, and by less extended, in general more minute, and often altogether irregular osseous tubes. It is formed in some animals (in the elephant, the horse, the ox, &c.,) as the outer covering of the enamel, particularly within the folliculus dentis before it is closed; but in these animals also it is secreted during the whole of life from the membrane surrounding

that part of the tooth which is concealed in the alveolus. In most animals with simple teeth, as also in man, it only invests that part of the tooth which is not covered with enamel. In the bradypus, in which no enamel is found, it covers the whole tooth.

"Its deposition round the root of the tooth increases as the cavitas pulpæ closes, and as the pulp itself correspondingly diminishes. The minute osseous tubes in the cortical substance then form immediate communications with the osseous cells and osseous tubes in the dental bone, so that the latter can now, when the pulp has as good as ceased to exist, receive the necessary supply of fluids from without. In certain animals the cortical substance presents also larger canals, which are of about the same thickness as the medullary canals in bone. In the cortical substance closing in some teeth the end of the cavity of the pulp which would else be open, those tubes open into the said cavity, and contain the blood-vessels which belong to the pulp itself. The larger tubes which are found in that portion of the cortical substance lying exposed beyond the gum, appeared empty, and are probably only the remains of the blood-vessels which were engaged in its formation. It is, however, still probable that even in this substance a circulation is kept up of peculiar fluids secreted from the blood, which fluids rise into the peculiar minute tubes and cells, in much the same manner as the sap rises in a plant.

"The layers of dental bone are deposited, as above described, from without inwards, the most external being thus always the first formed: in the cortical substance the reverse obtains,—its inner layers contiguous to the surface of the tooth are first formed, and afterwards the outer ones.

"The cortical substance presents no similarity to tartar;

and one of the best proofs that the latter is a mere deposit from the saliva, is the fact that we find thick crusts of it round artificial teeth."

The labours of Purkinje, Müller, and Retzius on the structure of the teeth have now been recorded, and the views entertained by these physiologists have been most ably investigated and confirmed by Mr. Owen, who has submitted to microscopical examination the teeth of several other animals both recent and fossil. From an excellent report of these researches read at the last meeting of the British Association, I have great satisfaction in finding, that he has arrived at the same conclusion, which I had previously embodied in the first announcement of this work, viz.—that the structure of the teeth, as manifested by means of the microscope, forms a new, distinct, and specific guide for classifying the different members of the animal kingdom, and determining their respective types. From the enduring nature of these organs, the characteristic modifications which they present, will form, as Mr. Owen has admirably pointed out, a most valuable accession to geological science.

I have now to give an account of a series of investigations in a different department of the subject, viz. on the *Developement of the Teeth.* Here we must not expect the brilliant display of beautiful construction and diversified forms with which the above details present us, but on the other hand we may hope to arrive at more practically useful results; for on a correct knowledge of their developement must the pathology of these organs be founded.

The authors of whom I have now to treat are more

especially Arnold, Raschkow, and Goodsir. The first and last of these gentlemen have devoted their attention exclusively to the early, or, as it is called, follicular stage in the developement of these organs. They consider that the process of dentition ought to be divided into three separate stages or subprocesses, and that this division is not arbitrary, but well marked and defined by obvious transitions in the progress of developement from the embryonic to the adult state—these transitions moreover being indicated by phenomena attendant on the position of the pulp in relation to the cavity in which it is contained. The first of these stages Mr. Goodsir denominates the follicular—the second, the saccular—the third, the eruptive. He further thinks that there may be said to be another stage, anterior to all these, the papillary—designating that state of the pulp when it is a mere papilla on the free surface of the mucous membrane; but he finally prefers to include this in the follicular stage, on account of its very brief duration.

Mr. Goodsir commences his paper* by an excellent account of the appearances presented on the dissection of fifteen human embryos, at different periods of developement after the sixth week. He found at the fourth month bodies which he describes as gelatinous and granular, situated between the pulp and the sac—the same bodies which a few years previously had forcibly attracted the attention of Purkinje and Raschkow, as we shall presently relate.

On the extrusion of the tooth Goodsir speaks as follows:—" At the moment, however, that the tooth passes through the gum, (when the non-adherent portion of the sac resumes its primitive follicular condition, its inner

* In the Edinburgh Med. and Sur. Journal for January, 1839.

membrane becoming continuous with the mucous membrane of the mouth,) the non-adherent portion of the sac shortens more rapidly than the fang lengthens, in consequence of which the adherent portion with the fang itself separates from the fundus of the alveolus, and the body of the tooth advances through the gum." (p. 27.) He at the same time considers it to be a law in the developement of animal bodies, "that parts or organs which have once acted an important part, however atrophied they may afterwards become, yet never altogether disappear so long as they do not interfere with other parts or functions." (p. 28.)

"The first or follicular stage," he says, "comprehends all the phenomena which present themselves from the first appearance of the dental groove and papillæ, till the latter become completely hid by the closure of the mouths of their follicles, and of the groove itself. It is upon this hitherto unknown stage of dentition that I have insisted so much in the former sections of this paper.

"The second or saccular stage is the one with which anatomists have been so long familiar, during which the papillæ are pulps, and the open follicles which contain them are shut sacs, when the tooth-substance and the enamel, constituting the teeth themselves, are deposited. It is during this stage also that some of the most interesting phenomena in the formation of the alveolar processes present themselves.

"The third or eruptive stage includes the completion of the teeth, the eruption and shedding of the temporary set, the eruption of the permanent, and the necessary changes in the alveolar processes.

"When viewed in reference to an individual tooth,

these three stages are distinct; but when viewed in reference to both sets, and to the whole process of dentition, they become somewhat intermingled.

"When considered in the latter point of view, we may state that the follicular stage commences at the sixth or seventh week, and terminates at the fourth or fifth month of intra-uterine existence; that the saccular commences at the termination of the first, and lasts for certain of the teeth till the sixth or eighth month, and for others till the twentieth or twenty-fifth year of extra-uterine existence; and that the third, or eruptive, commences at the sixth or eighth month, and lasts till the twentieth or twenty-fifth year." (p. 31.)

"Careful observation of the whole process of dentition in man, leads," says Mr. Goodsir, "to the following conclusions:—

"*Milk-teeth.*—1. The milk-teeth are formed on both sides of either jaw, in three divisions, a molar, a canine and an incisive, in each of which dentition proceeds in an independent manner.

2. The dentition of the whole arch proceeds from behind forwards—the molar division commencing before the canine, and the latter before the incisive.

3. The dentition of each of the divisions proceeds in a contrary direction, the anterior molar appearing before the posterior, the central incisive before the lateral.

4. Two of the subordinate phenomena of dentition also obey this inverse law, the follicles closing by commencing at the median line, and proceeding backwards, and the dental groove disappearing in the same direction.

5. Dentition commences in the upper jaw, and continues in advance during the most important period of its progress.

The first tooth-germ which appears is that of the *superior* anterior molar, which precedes that of the *inferior* anterior molar.

The apparent exception to this law in the case of the inferior incisive has already been explained.

Permanent Teeth.—6. The germs of the permanent teeth, with the exception of that of the anterior molar, appear in a direction from the median line backwards.

7. The milk-teeth originate, or are developed, from the mucous membrane.

8. The permanent teeth, also originating from mucous membrane, are of independent origin, and have no connexion with the milk-teeth.

9. A tooth pulp and its sac must be referred to the same class of organs as the combined papilla and follicle, from which a hair or feather is developed, viz. bulbs." (p. 35.)

Mr. Goodsir, it is true, was anticipated in some of his observations by Arnold, in the Salzburg Med. Chir. Zeitung, 1831, p. 236; but he has treated his subject so much more fully than the latter gentleman, that I have thought proper to commence this portion of the subject with an account of his researches. Mr. Goodsir himself quotes the substance of Arnold's statement, which is as follows:—" In an embryo of the ninth week we may perceive in both jaws, on the projecting edges of the gums, a proportionally pretty deep furrow, with ten depressions in it; a little later we may see a flat surface, on which there are many openings, communicating with small sacs, into which fine bristles may be passed. At the third month, the sacs of the second molars may be seen communicating with the cavity of the mouth by small holes.

The openings of the remaining sacs are soon closed by the mucous membrane of the mouth.

"The sacs of the permanent teeth are also formed immediately from the mucous membrane of the mouth, partly at the fourth month of fœtal existence, partly toward the end of that period, partly at birth. Once only, in a new-born child, I observed behind the most prominent edge of the gums several openings, which led to the sacs of the incisives and canines, and which are usually already obliterated before birth."

Valentin* says, "The dental border of the upper and lower jaw thickens at a very early period in the ruminantia and in pigs, when the embryo is more than an inch long ; in man, in the first half of the third month. In this border arise a series of oval, fibrous vesicles, which at first lie close together, and are separated from each other by a compact granular substance. This increases and is separated more and more, and runs through the above-mentioned stages to ossify in the form of alveoli, where the vesicles come into close contact with it. Within every vesicle is formed, probably somewhat later than this, the sac of the tooth, which, according to the general opinion, is in no way connected with the mucous membrane of the mouth. But according to Arnold, on the other hand, the entire sac is formed from this mucous membrane dipping into the groove in the upper and lower jaw." The subsequent details on this subject given by Valentin are so interesting that I cannot abstain from quoting them.

"The dental sacculus itself consists of two membranes; of which, according to Hunter, only the inner one, ac-

* *Entwickelungsgeschichte des Menschen*, p. 482.

cording to Blake only the outer one is vascular: Fox, Meckel, and E. H. Weber, on the other hand, state that both are vascular. Into this sacculus the vessels and nerves enter through an orifice opposite to the external side. Between the two membranes there is a fluid, which, according to Meckel, has at first a reddish and then a whitish yellow colour, but which Meissner says is as clear as water, or only turbid from a few flakes swimming in it, inodorous, tasting like mucus, easily drawn into strings or threads, containing a free acid, (probably lactic acid,) mucus, (but this is doubtful according to E. H. Weber,) a little albumen, phosphate of lime (more in that of the permanent than in that of the milk-teeth,) and muriatic and sulphatic salts. On analyzing this fluid in a young calf, its components were found to be essentially the same. It contained, however, more mucus, and a free alkali was found in the place of the free acid. Within the sacculus is developed the germ of the tooth as a small, soft, compact, roundish corpuscle, in which the shape of the crown is soon manifest, and subsequently the form of the neck.

"The teeth consist in general, as Purkinje and I shall demonstrate at length in our dissertation on the structure of bone, of fibres or tubes lying one above the other, and running like radii towards the central axis, and which are either straight or uniformly curved superiorly or inferiorly. Not a trace of osseous corpuscles is found between them in the fully-developed state. The first formative mass of the tooth consists likewise of a granular substance, which, however, is transparent where it is not granular. Here the globules arrange themselves in the same direction as is taken by the subsequent fibres: it almost seemed to me as if the globules themselves dis-

solved and ran into the fibres, the intermediate jelly playing here a more subordinate part.

"According to Meckel, the commencement of ossification is marked about the middle of pregnancy by the appearance of thin, delicate, elastic bodies (*scherbchen*,) which become gradually thicker and firmer. They correspond at first to the apices of the future teeth, and soon become thicker and harder on the masticating surface, whilst the tooth is still short, (being without a neck,) and hollow internally. As the tooth grows thicker, its cavity diminishes, and the dental germ disappears. The enamel is formed from the inner surface of the internal membrane (or leaf,) and is deposited on the osseous substance of the tooth. Its connexion with the tooth is tolerably loose in the fœtus. The period of its formation is the same as that of the tooth itself.

"With respect to the individual teeth, those of the lower jaw are formed earlier than those of the upper. First appear the two incisor teeth, then two molar teeth, and after them the canine in each half of the jaw, which collectively belong to the milk-teeth. Near them are shortly developed the sacs for the permanent teeth, which at first are seated on the sacs of the milk-teeth, are afterwards removed from these, and only connected with them by a thread, whilst they penetrate deeper into the jaw. (See Burdach's Phys. ii. 8. 475.) Hunter describes three centres of ossification in the incisor teeth, in the small molars two or three, in the large molars four or five, and in the canine one. Rudolphi describes two in the canine, whilst Cloquet states that there is only one in all the teeth; and Albinus, Blake, and Serres, assert that there is only one in the incisors. According to Meckel, the incisors and canines have only one germ, the molars, on the other

hand, several. According to Burdach, the crowns of the incisors are quite formed towards the end of pregnancy, and the root begins to be developed. In the canines a third part of the crown is formed, and in the first molar its upper part with its apices. On the second molar the four apices are still separated. In the permanent teeth the ossification of the crown of the third molar has sometimes commenced."

THE last work on this subject which we have to examine is another of the valuable productions of the present industrious and intelligent German school, which was published under the auspices of Purkinje, and which presents a striking proof of the efficiency and excellence of the system of medical education in operation in Germany. I allude to the "*Meletemata circa Mammalium Dentium Evolutionem*,"—an inaugural dissertation by RASCHKOW. This publication first saw the light in 1835, four years after Arnold had written on the follicular stage of developement. The department of anatomy under consideration has shared the fate common to almost every branch of the subject,—that is to say, what has been affirmed in it by one inquirer has been systematically denied by the next. Raschkow and Purkinje directly and positively contradict the opinions of Arnold and Goodsir.

"Arnold," says Raschkow, "has very recently brought forward an opinion upon the origin of the dental follicle, differing widely from the views of most writers. According to him, the dental follicles take their primal origin from the mucous membrane of the cavity of the mouth, the membrane in question being inflected into the alveolar groove of the upper and lower jaw." (p. 19.) And in the following page he adds, "Our

own investigations by no means allow us to adopt the opinion of Arnold; for we have never been able to see, either in the human fœtus, or in other animals, any such apertures. We have examined with this object the fœtuses of calves and sheep; but we never saw the mucous membrane of the mouth dip into the alveolar groove; and in the grooves themselves we never discocovered the deeper recesses which Arnold describes. It was always, on the contrary, clear to us, that the dental follicle at its origin is altogether separate from the gum, and is not closely attached to it by any intermediate connexion. Serres and Burdach were also in error when they said that the dental germ is a continuation of the nerve; for we have shown above, that at its commencement neither nerves nor vessels are to be seen in it." (p. 20.)

I have commenced with this portion of Raschkow's thesis, from its immediate connexion with the subject of which we have just been treating.

The new doctrines promulgated by Raschkow relate principally to the existence of what he calls the adamantine organ or pulp, situated between the follicle and germ, and destined for the production of enamel. He considers that this organ is very different from the internal layer of the capsule, and requires a separate and distinct consideration. He gives a very circumstantial account of his manner of proceeding in these investigations.

"The dental follicle," he says, "which contains the other formative parts of the tooth, is, as it were, its common chorion. It is surrounded by a dense network of vessels, which, distributed over it from the neighbouring blood-vessels, take their origin principally in that part where the root of the tooth is situated. In the same

manner the dental nerves send no small quantity of branches to this surface.

"The membrane itself of the follicle of the tooth is not to be considered as altogether fibrous, because its fibres are extremely soft, and are intermixed with much granular parenchyma. In the first weeks of the life of the fœtus (in the calf till about the eighth week), the follicle of the tooth has not yet grown into union with the gum; for both the epithelium of the latter, which then, compared with its state at subsequent periods, is found of a considerable size, and a certain peculiar stratum of its parenchyma, are easily separated from the dental follicle, so that in the coronal part it appears altogether free, and is only in the region of the dental arteries and nerves closely adherent to them.

"The internal plane of the dental follicle is smooth, and exhibits the appearance of a serous membrane. The membrane is everywhere free, except in that place where the dental germ proceeds from it. For the dental germ appears to proceed from nowhere else except from the internal plane of the follicle of the tooth, and from that part of it where the principal vessels and nerves enter into it, since between its substance and the membrane of the follicle there is a very close and uninterrupted connexion.

"In the internal chamber of the follicle or capsule, between its internal surface and the dental germ, another organ is also found, which at first, almost before the first stage of the growth of the dental germ, forms a nearly globular nucleus, of which the external surface appears in some slight degree to bulge out, and of which the internal substance presents a singular parenchyma, consisting probably at first, before evolution has been

further carried out, of the usual granular formative mass, similar to that of all the other organs of the fœtus; subsequently, however, by degrees it exhibits more clearly granulations of an angular form, which, connected together in various ways by filaments of cellular tissue, present the appearance of a kind of actinenchyma, such as may be seen in plants.

"This globular nucleus, which the capsular membrane surrounds, leaves a small interval between the latter, itself, and the dental germ, in which a peculiar fluid is found effused, which, when the capsular membrane is ruptured by continued pressure, flows freely out, and has the appearance of pure lymph, presenting no granules of any kind. This globular nucleus we have called by anticipation the organ of the enamel, because, from subsequent contemplation of the evolution of this organ, it will be rendered clear, that it is intended for the formation of the enamel substance, inasmuch as it is gradually transformed into the membrane which produces that substance.

"This takes place in the following manner.—The dental germ, in advancing further and further into the interior of the dental follicle, makes first only a slight impression on the globular mass of the enamel organ, but this impression is rendered gradually deeper as the growth of the germ proceeds. When the dental germ has penetrated further into the hollow thus made, it appears narrower towards the base, and thicker under the apex, and so is enclosed around on every side by the parenchyma of the enamel-organ, which thus assumes the appearance of a hood, covering the dental germ when advanced in its developement, and capable of being separated from it without difficulty, and without any injury,

either by the compressor, or in another manner by being placed under water. This enamel-hood, so to call it, presents, towards the basilary part of the dental germ, a margin which is at first obtuse, afterwards sharp, but which is always free at every part: moreover, it still appears to be altogether as freely situated between the capsular membrane and the dental germ as previously when it existed under the form of a globular nucleus, and is probably everywhere surrounded by the lymph above mentioned. The inquiries respecting the connexion of the enamel-organ with the capsule have not yet been completed. At first it appears to be altogether free in the capsular fluid; subsequently, however, at the extremity of the capsule, that is to say, in the coronal region, some connexion exists by means of loose vessels; moreover, the parenchyma of the organ itself is seen to be pervaded by numerous capillaries, and these facts prove that from the commencement this organ is connected with the capsule. If this is the case, we may assume that the dental germ takes its origin from that extremity of the capsule which is towards the root, the enamel-organ from the coronal extremity, since both these organs, arising at opposite points, approach each other, are adapted together, and contribute together towards the formation of the tooth.

"When the enamel-organ has assumed the form of a hood, a peculiar organ is perceived on the surface of that cavity in which the dental germ is lodged, consisting all of it of short uniform fibres placed perpendicularly to the surface of the cavity, and forming, as it were, a silky lining to the whole of the latter. In a transverse section of the enamel-organ, this stratum of perpendicular fibres is clearly seen, and can be accurately distinguished

from the other stellated parenchyma of the substance which we may here call the pulp of the enamel.

"This stratum of fibres is at first strictly connected with the pulp of the enamel, and seems to originate in the immediate transformation of the latter. Afterwards it separates itself from it more and more, and only adheres to it by some few filaments of cellular tissue. After it has freed itself in this manner, and become, as it were, independent, it may justly be considered as a genuine membrane, and, on account of its function presently to be noticed, we have already termed it the membrane of the enamel. The greatest part of it can then easily be separated from the circumjacent pulp of the enamel, only a thin stratum of the latter remaining adherent, except in the hollows of the molar teeth where the parenchyma of the enamel-pulp remains aggregated till the period of eruption; but neither then, nor at any preceding period, does it present any distinct traces either of vessels or nerves.

"When we examine more closely the membrane of the enamel, its internal surface is seen to consist of hexangular, nearly uniform corpuscules, visible only through a magnifying glass, towards the centre of each of which is a round eminence. These corpuscules are nothing more than the ends of short fibres, of which the whole membrane is composed, and which, being pressed together, assume freely the hexangular form. These same hexangular corpuscules are disposed in regular series,—from which arrangement it follows that they correspond exactly to the rows of enamel fibres formed from them.

"At the inferior extremity of the enamel-organ, the enamel-membrane is never so evidently separate from the parenchyma as in the other parts; and it may hence be

rightly concluded, as the enamel-substance is formed there at a later period, that the enamel-organ continues to grow anew there, till the enamel-substance has been perfectly formed. In the molar teeth of the ruminantia, this organ appears, in part at least, to be connected with the capsule in such a manner that it seems to receive thence continually by proper vessels a sufficient supply of nourishment and of material for its increase, whilst, on the other hand, it disappears in other parts where its functions have been performed. This appears to obtain much more in those teeth, which (like those of swine and the rodentia) never cease to grow.

" Hitherto we have only treated of the dental germ in so far as was necessary towards the description of the dental follicle and enamel-organ: we now proceed to examine more closely its organic structure and developement.

" The dental germ is doubtless a product of the internal wall of the dental capsule, seeing that the substance of its parenchyma is indissolubly connected with the capsular membrane, and there being the same origin, moreover, for the vessels and nerves of both. The doctrine which some have promulgated, that the dental germ is a continuation of the dental nerve itself evidently cannot be maintained; although it cannot be denied that from the very commencement there exists an organic connexion with the nerves, as is the case in all parts in the interior developement of which nerves are formed.

" At first the dental germ presents a parenchyma consisting of almost uniform globular granules, in which neither nerves nor vessels can be discovered. Subsequently vessels appear in it; but a long period must still elapse before any trace of nerves is visible in it. When the deve-

lopement of the tooth is much more advanced, and its vascularity has long been evident, true nervous filaments are also discovered. The same rule obtains here which is manifest in all the parts of the fœtus during developement. First is seen the formative parenchyma, which has no specific character, (*indifferenti quæ sic dicitur indole,*) and which, though it contains the germs and seeds of nerves, presents as yet no true nerves themselves.

"Perhaps no part of the body exists where the extremities of the nerves present so evident and beautiful an appearance as in the dental pulp. For displaying this, it is best to select the pulp of an adult tooth. We have examined it in the human subject, and in several of the rodentia and ruminantia. The nerves, after they have severally, or in bundles of several branches, entered the pulp of the tooth, recede more or less from each other; and so in simple filaments, partly separated and partly combined, proceed to the extreme apex of the crown, where again they divide by degrees into their simplest filaments, which, swelling like rows of beads, constitute the primitive series of variously interrupted nervous articuli, being accompanied in their course by a delicate cellular tissue, in order that they may not deviate from a right line. At length, under the apex, they again form a plexus, from which filaments are given off, terminating like 'penicilli' at the extremity of the apex, where they are surrounded by a network of vessels. In the incisors of a man of about thirty, we found a great abundance of filaments in comparison with other parts of the body, and also with the teeth of other animals which we have examined; and hence may be deduced the great sensibility of the tooth, especially in man.

"It is worthy of mention, also, that in the teeth of the

hare, the sow, and the stag, especially in the molars, we constantly found stony masses. They were semi-transparent, for the most part oval, and rounded bodies, which were situated in the axis of the dental pulp towards its apex in irregular rows, never extending the whole length of the dental pulp, but only to a greater or less distance from the coronal extremity. Such examinations of the dental pulp are facilitated by the use of the compressor; but without its assistance the same results may be obtained, though with more trouble.

"In the dental germ, from the very first period of its formation, we invariably find the dental pulp together with a peculiar pellucid membrane without any characteristic organisation, which covers the surface of the pulp from the base to the apex. This we have denominated the præformative membrane, seeing that in it the formation of the dental substance commences, and that it always precedes the latter.

"The parenchyma of the dental substance is composed, as we have already mentioned, of uniform, globular granules, with no evident filaments of cellular tissue; by which circumstance it is best distinguished from the filamento-granular parenchyma of the enamel-pulp. Afterwards an abundance of nerves and vessels make their appearance. Vessels with several small stems communicating with each other enter into the interior of the pulp, partly proceed to the other surface, and there, principally in that part where the dental substance has begun to be formed, their branches are distributed, constituting a network of capillary vessels. But where the formation of the proper dental substance has not commenced, and the præformative membrane alone is found,

no evident network of vessels is yet perceived. This fact offers a certain analogy to what takes place in osseous substance, where also networks of sanguiferous vessels are not rendered evident till the proper earthy substance of the bones is found deposited.

"The præformative membrane belongs so peculiarly to the dental germ, that it uniformly exists from its first commencement, so that by its presence, should there be any doubt, the dental germ may be distinguished from every other organ; for example, from the capsular membrane, or the enamel-organ. With respect to its consistence, (if I may use the expression,) it displays a remarkable tenacity, for under the compressor, even when continued pressure is exercised, it is only ruptured with difficulty, and before being ruptured it not unfrequently swells into a considerable vesicle. Immediately under this membrane are found granules of the parenchyma of the dental germ, more regularly arranged, and more longitudinally extended, placed uniformly on the membrane, partly at right angles, and partly at somewhat acute angles.

"When the developement of the dental germ has made considerable progress, and the time for the formation of the dental substance approaches, a number of elevations (*tumulorum instar*) are found in the præformative membrane, at the apex and its vicinity, which are probably afterwards transformed into the undulating ridges of the extreme surface of the dental substance, in which the enamel fibres are firmly placed. At this period also, immediately under the membrane, the proper dental substance is formed, the process commencing always at the coronal apex, and thence uniformly advancing on the one

hand towards the coronal fossæ, and on the other towards the root of the tooth.

"At first the dental substance appears to be composed of fibres variously curved, contiguous, and adherent at their convex sides, and is already hard and osseous (*ostoidea.*) In the apex itself these fibres spread equally in all directions, but towards the lateral parietes the longitudinal direction prevails; whilst fibres whose course is sinuous, which are arranged contiguously in an uniform manner, and which leave at their concavities interstices between each other, proceed everywhere from the coronal apex to the root. Only the extremities of these are still soft; the remaining parts harden in a very short time, unlike the substance of the enamel, in which the fibres, long after they have been deposited, appear soft and easily to be broken up. Whilst these are being formed, the præformative membrane also becomes of a stony hardness, except at the margin of the recently-formed dental substance, where it is soft and easily rent. The substance of the enamel begins to be formed at the same time with the dental substance.

"We have now to consider in a similar manner from its first commencement, the process of formation of the dental substance, with regard to its thickness. After a stratum of dental fibres has been deposited between the parenchyma of the dental germ and the præformative membrane, which is now also ossified, the same process is continually going on from the external region towards the internal, the parenchyma of the dental germ supplying the material. This parenchyma decreases in proportion as the dental substance increases, and is withdrawn as it were into the dental cavity, which is gradually contracted. The convex curvatures of the dental

fibres, which increase in breadth as they proceed from without inwards, and which in mutual apposition form continuous canals, rise at the periphery of the dental substance, proceed with many delicate windings to the pulp of the tooth, and its cavity, where their mouths open, and serve there, as long as the formation of the dental substance lasts, towards gathering new fibres, until at length these apertures also, in the last stage of the developement of the tooth, are closed by a somewhat different substance, which is yellow and semi-transparent, and which has been compared by Blumenbach to corneous tissue.

"Whilst the growth of the dental substance is thus advancing, the dental germ increases in the same manner at the radical extremity. Although at first it only formed the extreme apex of the crown, by degrees its growth extends into the body of the tooth, and as the developement proceeds it is narrowed into one or more dental roots, which, after the dental substance has made still further progress, stretch into the dental cavity, like broad canals filled with a considerable quantity of dental pulp. These canals, however, when the formation of the dental substance is further advanced, become narrower by degrees, and when it is completed, give entrance to nerves and vessels only by one or more very small foraminula. We say by more than one aperture advisedly; for in the incisors of the stag, and in some rare cases of the human subject, we saw several canals, which in a transverse direction penetrated into the substance of the root of the tooth, so that in this respect it presented considerable similarity to true osseous substance. We were not able to decide whether that layer of osseous substance which, commencing at the neck of the tooth, invests the surface

of the roots, is produced by the dental pulp like the other dental substance, or whether it has not its origin at a later period in the transformation of the capsular and enamel-membranes into true osseous membrane, and belongs thus to true bone. This perhaps takes place also in the cement of horses and of ruminantia, where the whole is similar to true osseous substance—but on this point we have had no experience to instruct us.

"We proceed now to explain the formation of the substance of the enamel. This is not, as previous writers have erroneously maintained, a deposition (like that observed in the formation of minerals, or as if it were a crystalline sediment) from the lymph surrounding the dental germ, but its formation also is effected by a true organic process. We have already accurately determined the origin, structure, and form of the organ by which the enamel-substance is formed. It still remains to explain more closely the nature of its function, as it appears to us. The organ from which the substance of the enamel is immediately formed is the enamel-membrane which we have described above. Each of its short perpendicular fibres is to be regarded as an excretory organ or gland, destined for the secretion of the enamel-fibre corresponding to it. At the same time with the first formation of the dental substance and *pari gressu* from the coronal apex to the root, each one also of these fibrillæ, whilst it places itself on the now hardened præformative membrane, begins to deposit in due order the primitive part of each enamel-fibre, so that each one of these enamel-fibres, carefully examined under a microscope, shows that it is composed of layers disposed in a transverse direction. At the period when these fibres are being formed, an organic lymph seems to be secreted from the parenchyma of the enamel-mem-

brane, which is found between its glands, and this penetrates between the individual fibres, and renders their whole substance soft. Subsequently, however, the latter, probably by some chemico-organic process, enters into an intimate combination with earthy substances, and so forms the animal base of the enamel-substance, which (after they have been dissolved by acids) again presents itself under the form of a mucous tissue; this, however, on account of its extreme delicacy, cannot be easily discerned by the naked eye, nor without the aid of a magnifying glass.

"In order to explain the various curvatures of the enamel-fibres, we must suppose that the enamel-membrane also, during the progress of formation of the enamel-substance, changes the situation of its fibres by certain brief movements, while it partly retires from the internal region, and is dilated by the increase of the enamel-substance in thickness, and partly by following the curvatures of the individual enamel-fibres along the sides and longitudinal direction of the tooth, experiences slight changes in its situation either in single or successive portions. In those teeth of which the crowns only are covered with enamel-substance, the enamel-membrane also does not extend beyond the crown itself, and there principally the enamel-organ, like a hood, evidently unattached, can be separated from the dental germ. But in those teeth of which the growth has no fixed limit, as in the rodentia, in the tusks of the sow, in the pachyderms, &c., the extent of the enamel is not so contracted; and for this reason we are led to conclude, that from the beginning there are no such bounds of the enamel-membrane, nor any formation of a hood. Nay, in this case the enamel-membrane, especially after the eruption of the tooth, always

assumes the form of a girdle of greater or less breadth, which, surrounding the basilary part of the tooth, is continually being changed towards the crown into an osseous membrane, which is always arising anew about the root, and in the middle always depositing fresh enamel-substance. If, however, we regard the different distribution of the enamel substance, in respect to quantity, over the surface of the dental substance in the different kinds of teeth, and in the different classes of animals, we shall perceive that another peculiar circumstance also contributes to the especial formation of the enamel-organ: respecting this, however, no accurate investigations have yet been made. There are two principal directions observable in the motions of the teeth with regard to each other, in grinding and breaking down food; the one perpendicular, in carnivorous, frugivorous, and insect-eating animals—the other horizontal, in the ruminantia, rodentia, and most of the pachyderms. To these directions in which the teeth are worn down, the distribution of the enamel on the dental substance corresponds. Where the tooth is worn in a perpendicular direction, the greatest quantity of enamel is deposited on the coronal plane, and also on the apex; but where it is worn in a horizontal direction, there exists, even at first, only a thin and easily pulverized layer of enamel on the apex of the crown, but it is found in great abundance on the dental parietes, which are in various apposition to each other. This obtains principally with regard to the molar teeth; the incisors and canines exhibiting but little difference, and their function being in all cases almost the same. To this distribution of the enamel-substance, the first formation of the enamel-organ ought to correspond. In the first kind

of direction of the teeth, the principal mass of the parenchyma ought to be found at the coronal apex ; but in the other kind, partly on the parietes of the tooth, partly in the coronal fossæ, (in the ruminantia and in horses,) partly also in the lateral recesses of the tooth (in the rodentia)—but on this point no accurate investigations have yet been made.

"We see from the foregoing that the dental substance is formed in an opposite direction to the enamel. For in the one case the pulp of the dental germ is covered with the fibres of the dental substance, and, after it has deposited a layer, recedes from the external to the internal region: this substance, therefore, increases from the circumference towards the centre; but the contrary takes place in the deposition of the enamel. Its first layer which touches the dental substance is most internal, whilst each subsequent one approaches nearer the periphery, towards which the enamel membrane recedes. The direction of this, therefore, is from the centre to the circumference. The formation of the dental substance has a more organic character; and in some respects reminds us of the formation of osseous substance, from which, however, it still greatly differs. The formation of the enamel, on the other hand, is of a more mineral character. It may best be compared to the secretion of the calcareous shell in the duct of the egg of the bird, which Hunter has already touched upon. It would be altogether false, however, to regard it as a true process of crystallisation, for its fibres are curved in various ways, and are arranged with an organic object: moreover, no small quantity of organic matter is contained in its substance; and the absence of all the strict lines of crystallisation, as well as the mode in which the fibres are seve-

rally secreted, sufficiently show the peculiar difference between these processes. We have already mentioned the law of polarity which obtains in the whole course of dental developement, and we leave to the reader more closely to study the point which is called indifferential, because it is contained in the contact of both substances, the dental and the enamel; further, the polaric opposition between the enamel-membrane and the præformative membrane, between the enamel-parenchyma and the dental germ, and, finally, between the region of the gum and that of the nerves of the capsule of the tooth.

"This would be the most fitting place to treat more at large of the formation of the cement, of which we have already made mention. As, however, we ourselves are deficient in experience with regard to many points belonging to this subject, and the opinions of authors respecting it are vague, we have only ventured here to form our own opinion derived partly from the examination of the substance of the tooth with the microscope, in reference to its structure and developement.

"The cement is always placed externally to the enamel. It is consequently formed at a later period, and after, indeed, the formation of the latter is completed, and the enamel-membrane has disappeared, or been in some way transformed. At first the enamel-pulp is situated close to the enamel-membrane; and if it does not disappear together with the latter, it is perhaps that which serves to deposit the cement. But if it does vanish with this membrane, there then remains only the capsular membrane to answer this purpose, which, however, at the advanced period when the cement begins to be formed, doubtless coalesces with the periosteum of the alveolar parietes. The following fact greatly supports the opinion that the

enamel-pulp is transformed into the organ which secretes the cement, viz. that in the deep fossæ and lateral recesses of the teeth of ruminantia, of horses, and of rodentia, after the formation of the enamel-substance has been completed, the simple enamel-pulp remains without any contact with the alveolar parietes, and it is here, therefore, the only organ there can be for the production of the enamel. Finally, the enamel pulp on the external surface of the tooth, where it comes into contact with the alveolar parietes, may, together with the capsule, be combined with the periosteum,—and this supposition is favoured by the circumstance, that the granular and tubular structure of the cement presents the greatest similarity to that of true bone.

" This observation, too, ought not to be omitted, that that membrane which clothes the alveolus, and corresponds to the periosteum, displays even at the first glance, but principally where it is joined to the external parts, a loose texture, similar to the pulmonary tissue, and which, when examined under a glass, displays, besides a large quantity of sanguiferous vessels, a number of air-canals of considerable diameter, to the presence of which the soft and elastic nature of this tissue is owing : their object, perhaps, is to afford greater mobility to the advancing tooth. We have mentioned this subject in order that the attention of the reader may be directed to the air-vessels which are met with in the animal body, and to correct rather than confirm the belief respecting them. It ought, moreover, to be mentioned, that on the interior surface of the lobes of the gum which surround the protruding molars of the young ruminantia, similar rows of perpendicular fibres are found to those which we described in the enamel-membrane. It is a question how far they have the same

function, and whether it is not probable that the enamel-fibres do not continually derive fresh materials of increase from this quarter.

"The developement of the gum is connected in the most intimate manner with the history of that of the teeth, the maxillary bones, and the alveoli. In treating of the developement of the teeth, we were unwillingly compelled to devote some attention to observations respecting the developement of these parts. Thus, for example, we are struck with the great firmness of the inferior maxillary bone at an early period, compared with that of other bones of the fœtus, and also with the comparative perfection of its nerves and vessels.

"With respect to the gum, the dental cartilage, as it is called, in man and other mammalia, is chiefly worthy of mention. It is not true cartilage, for the peculiar granules which principally characterise that substance are wanting in its parenchyma, which, however, is otherwise firm. In the first place, there is found in this dental cartilage a tolerably thick stratum of the epithelium of the mucous membrane, which corresponds to the epidermis of the external skin, and like it, but in a much more perfect manner, consists of various polyedric scales placed one above the other, several of which present an orbicular spot in their centre. Under this epithelium is situated the hard parenchyma of the dental cartilage, which, in my opinion, corresponds to the chorion of the skin, inasmuch as it is granular, abundantly supplied with vessels, and interwoven with numerous firm and fibrous filaments. In this tissue, in the new-born infant, closed cavities are constantly found dispersed here and there, which are filled with scales similar to those of which the epithelium is composed. These, without any doubt, are those glands which

Serres has already described, and which, he most erroneously states, contribute afterwards to deposit the tartar of the teeth. That they are connected with the formation of the epithelium is proved by the scales; but in what manner has not yet been ascertained. Perhaps, also, they are the same follicles which Arnold describes in a new-born infant as apertures, situated near the most prominent margin of the gum, and which, in his opinion, lead to the sacs of the incisors and the canine. (See Fränkel, Dissert. de Dent. Human. Struct. p. 4.)

"In the first stages of developement, (as far as we are able to judge in certain animals (the calf, the sow, and the dog,) the stratum of epithelium is much thicker than afterwards. The conformation of its scales is not yet such as in the period which precedes birth; but they present a parenchyma very similar to the cellules of plants—every scale which afterwards appears as such presenting itself then as a polyedric cellule, consisting of very tenacious membrane, and containing a globular drop of fluid. These cellules were ruptured by pressure, and lymphatic fluid was poured out. In the course of developement they are probably flattened and changed into the polyedric scales. At first, the stratum of epithelium is most easily separated from the subjacent parenchyma of the mucous membrane. It presented, in a calf of nine weeks, above the molars, in the surface separated from the teeth, a double series of processes like epistomia, which, although lodged in the corresponding cavities of the parenchyma of the gum, still did not, as it at first seemed, penetrate into the cavities themselves of the molars, being evidently separated from these by the capsular membrane and enamel-pulp."

It will be interesting, now that we have brought down our Historical Sketch to the present time, to inquire what at present is the real amount of our knowledge in the science of Odontology. The result of such an inquiry is unfortunately far less satisfactory than we might at first be led to anticipate from the number of works which have been published on this subject, and from the number of eminent men who have devoted their attention to it. The statements of writers are very much at variance, and not only do opinions differ, but the facts on which those opinions are based, we find everywhere described in a different manner. How such discrepancies, as we here find in abundance, can have arisen in the simple field of anatomical description, it requires no little diligence and perseverance to explain. They have partly their origin, doubtless, in the infinite variety of aspects presented by the teeth in their constantly varying condition, and in the numerous stages of developement through which they pass. At one period, a particular membrane is highly vascular, and at another, in such a state of atrophy as to induce the observer to consider it as absent altogether. The arrangement of the parts appears at one time so confused, as at a superficial glance to seem destructive of the vital functions. Hence the anatomists, whose observations have been confined to the state of these organs at particular

periods, have come to conclusions of a correspondingly limited character. It is no easy matter to accomplish a complete investigation of the developement of the teeth, and more particularly in man, from the great difficulty in obtaining an adequate supply of subjects at a sufficiently early stage; in short, it cannot be denied that no department of anatomy is more complicated, and that none presents more difficulties to the investigator than the anatomy and physiology of the teeth: none, however, on the other hand, is more fraught with interest to the investigator of minute, organic structure.

Let us now attempt to test the value of our present information, by inquiring what assistance it is able to afford us in practice.—In treating the urgent symptoms attendant on dentition, a knowledge of the true nature of the capsule, the pulp, and the surrounding parts, is required. On these points one of the latest inquirers is Arnold, whose observations tend to prove that the early stage of dental developement presents an open follicle of the mucous membrane, which afterwards closes and becomes the capsule. The observations of Arnold have been contradicted by Raschkow and Valentin, and again corroborated with many circumstantial details by Mr. Goodsir, published in the Edinb. Med. Journ. for Jan. 1839. This subject may therefore be considered to be still *sub judice*.

With respect to the capsule itself, some writers contend that it consists of two layers; others, that it is composed of one layer only. Some maintain that both its layers are vascular; others that vessels are exclusively found in the external layer; and others, again, that they are discovered only in the internal one. Many authors assert that the capsule has also the office of a periosteum; whilst in several works we find it stated, that the latter consists

of two distinct laminæ. There are writers who hold that the pulp is covered by a proper membrane, which they conjecture is a continuation of the periosteum of the jaw; but the very existence of this membrane is denied by others: a third opinion is, that a proper membrane exists, but that it only partially covers the pulp. The observation of only a limited number of subjects must be the cause of this diversity of opinion, as there can be no doubt that the capsule consists of two layers, that both these layers are vascular at certain periods of their developement, and also that a proper membrane exists on the surface of the pulp.

Anatomists are far from being agreed as to the source whence the capsular vessels are derived: they have their origin exclusively in the gum, according to some, and in the dental trunks, according to others. My own opinion is, that they derive their origin from both these sources.

There is one opinion which has been uniformly maintained by all writers on this subject, viz. that when the teeth of man, or other analogous simple teeth, are extruded, the enamel is divested of all external covering, and exposed immediately to the atmosphere, denuded of both the envelopes of capsule and mucous membrane which it possessed during what has been called the saccular stage; and this denudation has always been supposed to be effected by the disruption of these coverings. My own views, however, on this point, which are contained in a paper read some time ago before the Medical and Chirurgical Society, are different from those generally received; and I have no doubt that I shall be able to prove that it is a process of absorption, and not of disruption, by means of which the tooth is emancipated, and that when perfected and extruded it is still invested with

a capsular covering. This covering, as it is seen to be continuous with the crusta petrosa, I consider to be analogous to it, as the latter has been found to invest the whole tooth in an enlarged state in many animals, and in a particularly interesting form in the orycteropus,* bradypus, walrus,† &c. In my collection are numerous preparations of this covering on the teeth of man, on the incisor of the calf, and on the simple teeth of many other animals. I have detected it, indeed, on the teeth of so many animals, that I presume it will be found universal. By means of acid, I have removed it in the shape of a membrane from the surface of these teeth; and in delicate dry sections prepared in a peculiar manner, I have been enabled, with the microscope, to examine its structure. In man it forms a thin layer, of a darker colour than the enamel; it is continuous with the crusta petrosa which covers the fang, but differs from it in not always containing corpuscules. On the incisor of the calf this covering is very distinct, and generally presents corpuscules. The extreme difficulty which is experienced in getting a fine section of a tooth without this membrane being removed in the process of reduction, is, probably, the cause of its having been overlooked by previous observers.

It has been left to the sagacity of Raschkow, one of the most recent writers in this department, to explain what Herissant calls the *temporary gum.* Other writers have presumed that the tooth, before its extrusion, has a cartilaginous investment, forming of course a considerable obstacle to its progress; but the truth is, that this covering, instead of being cartilaginous, is merely composed of thickened epithelium. The details of the developement

* Plate C. 1, Fig. 4, *a a.* † Plate C. 3, Fig. 1, *a.*

and structure of this latter substance will be given in an early chapter of the present work.

The minute and interesting bodies first noticed by Cloquet and Serres, and denominated by them the dental glands, have been denied to exist by some inquirers, and one writer has gone so far as to assert that they are "too manifestly a mistake to require any particular refutation." They certainly, however, do exist, though probably they are neither entitled to the appellation of glands, nor endowed with the permanent functions assigned to them by Serres and Blandin—and in my opinion they merit very attentive consideration.

A knowledge of what may be called the periosteal functions of the capsule, in connexion with those of the true periosteum of the socket, is also of great practical importance; for many sound teeth are lost from suppuration of the membranes connected with their sockets and roots: but on this subject, also, the opinions of writers on the teeth are contradictory in the extreme. Monro maintains that the teeth have no periosteum of their own, "but that it is supplied by the reflected membrane of the gums."* Hunter considers that the periosteum of the alveolus "is common to the tooth and socket."† Blake says, that "the external periosteum of the jaw seems lost in the gum;" but that the teeth are "attached to the alveolar cavity by a strong periosteum."‡ Fox considers that the periosteum "is reflected from the alveolar process on the root of the tooth."§ Delabarre considers that the socket and the root of the tooth have each a periosteum of their own; but that both are very intimately connected.

* Monro on the Bones, p. 114.

† Hunter's Natural History of the Teeth, p. 43.

‡ Blake, p. 169 and 33.

§ Fox, p. 11.

Meckel describes the "root and neck to be covered by a thin membrane, and the alveolar cavity to be lined with a thick, fibrous membrane," which is "continuous with the gum."* On this subject Mr. Bell expresses himself as follows:—"The periosteum of the maxillary bones, after covering the alveolar process, dips down into each alveolar cavity, the parietes of which it lines. From the bottom of the cavity, where the vessels and nerves of the internal membrane enter, it appears to be reflected over the root of the tooth, which it entirely covers as far as the neck, at which part it becomes intimately connected with the gum."† "At this stage," says Blandin, "we can recognise perfectly the continuity of the capsule with the mucous membrane of the mouth." "The capsule," he adds, "is formed of two layers,—an external one, of a fibrous nature, confounded with the *proper periosteum* of the alveolus; and an internal one more vascular than the other, and adherent to the root of the tooth."‡ Thus Blandin allows the existence of not less than three distinct layers of membrane interposed between the root of the tooth and the bony socket.

From these numerous discrepancies, to which I need add no more, it is evident that the above inquirers cannot all have pursued the simple method of investigation which M. Delabarre tells us he had determined to adopt:—"Le scalpel, le burin, et la loupe en main," says he, "je promenerai mes regards sur la nature comme étant le seul livre qui ne peut pas nous egarer." In the want of a proper "loupe" is probably to be sought the origin of many of the above discrepancies. The hitherto unsettled state of

* Meckel, Man. d'An., vol. iii. p. 325.

† Bell on the Teeth, p. 42. ‡ Blandin sur le Système Dentaire, p. 76.

our ideas on the developement of these parts is such, that we must not be surprised that some of their diseases are not well understood, are often found very untractable, and run frequently into a malignant state.

It appears to me to be certain, that the external periosteum sends a continuation to line the cavity of the alveolus simply, and that the fang of the tooth continues invested by the original capsule.

We have seen that all writers on the Anatomy and Physiology of the Teeth have discussed the question, whether these organs are to be regarded as positively belonging to the osseous system, or whether they are to be considered as productions of the tegumentary membrane. The explanation of many of the peculiarities connected with the diseases of infancy, depends on a proper solution of this difficult question. The origin and nature of decay in the teeth, and its treatment, as well as many other points, cannot be satisfactorily discussed before this subject is settled. Authorities here again are almost equally divided, and indeed no department of the science of odontology has given rise to a greater number of conflicting statements than we here encounter at its very commencement.

Ambrose Paré considered the teeth to be *vascular*, and liable like other bones to inflammation and suppuration. Leeuwenhoek, in 1678, *suspected* them to be vascular or endowed with vitality, as he considered them to be composed of " small, straight, and transparent pipes." Monro, Hunter, Blake, and Fox regard them as *bone*. Monro, however, is undecided as to their vitality. Hunter *thinks* that they have " no circulation, *but* a vital principle." Blake believes it to be " incontestable" that vessels, both " circulatory" and others, are present in the tooth, and

that there are vessels passing from the pulp to the ivory. Fox dilates largely on their great analogy to bone, which he regards as perfect except as to their density. He considers that their diseases also are similar to those of bone, and thinks, with Ambrose Paré, that they "have their origin in inflammation." G. Cuvier and Serres deny both the vitality of the teeth, and that their structure is strictly speaking osseous. Serres, who also perfectly expresses the opinion of Cuvier, speaks on this subject as follows:—"Tout me porte à croire que le tissu propre des dents n'est pas le même que le tissu propre du systême osseux;" and at p. 52 of his work he further says, "N'y a point de nerf qui se distribue dans son tissu, puisqu'il est exhalé, et, pour ainsi dire, inorganique (anatomiquement parlant.)"

M. Delabarre is the next author in chronological order, and we find him in direct opposition on these points to Cuvier and Serres. He is here a follower of Bichat, whose testimony is directly in favour of the vitality and osseous character of the teeth. Meckel is not to be classed on this subject with any of the preceding: his views resemble in some respects those of Cuvier, and in others those of Bichat.

F. Cuvier inclines to think the analogy between the teeth, and hair or horn, more perfect than that between the former and bone. He describes the tooth as "dépourvue de vaisseaux et de nerfs, et privée de tout rapport immediate et necessaire avec les autres organes." On the points under consideration, Rousseau is very undecided; but he still states distinctly that vessels pass from the pulp into the ivory. Bell regards the teeth as osseous and vascular; and states that there is a vascular communication kept up between the pulp and the ivory.

But all this is flatly contradicted by the next writer, Blandin, who maintains that all that has been advanced on the other side of the question is marked "au coin de la plus pure hypothèse."

Mr. Tomes, the latest labourer in this field of inquiry—the author of an excellent paper in the Medical Gazette, No. 585—adopts the conclusion, that "of the several parts which have been treated of, all, save the enamel, are vascular, and he would not deny even to this all connexion with the circulating fluids."

Thus on each side we have writers of equal authority; and the points at issue remain altogether unsettled by any positive anatomical demonstration, although they are of great practical importance, and so prominent as to demand the active scrutiny of the student of nature.

In short, the impression left on the mind of the student, after having perused the works which have been published in this department of science is, that almost every point requires to be investigated anew.

How various and contradictory are the opinions of writers on the composition and structure of the teeth! Hippocrates taught that they were composed of *hardened fat*. Leeuwenhoek was the first who stated that their structure is *tubular*, and this doctrine, after having been forgotten for one hundred and sixty years, has lately reappeared in a most attractive garb. Monro believed that these organs are *longitudinally fibrous:* Fox, that they were *deposited in layers*. G. Cuvier says, "that they are *neither cellular* nor *fibrous*, but composed of *laminæ*." Bichat held that they were analogous to *rock*, and *fibrous*; Serres, on the other hand, sees *nothing like fibres* in them. Rousseau describes their structure as being *longitudinally striated*. Blandin, who wrote so late as

1836, tells us, that they are composed of *plates*, situated parallel to their external surface; and this statement was made a year after Purkinje, and others, in Germany, had so beautifully demonstrated their fibrous texture. This latter subject has been further elucidated in the most complete manner by Professor Retzius; and that the structure of the ivory is at any rate fibrous, could not now be denied even by M. Serres, or by those who have stood up for its rocky or simply stratified character.

The labours of Retzius and his contemporaries must be considered as a most splendid contribution to minute anatomy; but I still think that the evidence in favour of the existence of a *system of ramifying tubes* in dental bone or ivory, requires much further examination and corroboration, before we can be justified in adopting a theory tending to overthrow many received opinions, results of ordinary experience. The difficulty in arriving at just views of this subject is partly owing, I think, to the circumstance that writers have comprehended very different structures under the same term. All the diversified textures entering into the composition of the *bodies* of different teeth have been described as dental bone or ivory; and it is unfortunate that the advocates of a tubular system have not been much more precise than their predecessors in defining the specific nature of the various dental structures, in which they state that they have traced hollow fibres.

Like all newly-propounded doctrines, the theory of a tubular system, as laid down in the preceding pages, will be found to present some internal contradictions. "It can *scarcely be doubted*," says Retzius, "that the minute tubes in dental bone, in the cortical substance, in common bone, and in the horns of deer, as well as the cells with which they are in connexion, are a peculiar kind of

vessels containing a nourishing and supporting fluid." In another part of his work, however, he says, "with respect to the contents of the canals, I, as well as Professor Müller, have found that they consist of an inorganic or earthy substance, which appears white when viewed on a dark ground, but which disappears when the preparation is placed in diluted muriatic acid. When the light falls into these canals, this matter is seen to be composed apparently of infinitely fine particles, adhering together in lumps. The greater or less number and distinctness of these lumps seem to depend on the degree in which the preparation has been penetrated by water, oil, or turpentine." "That the small osseous tubes and cells," he afterwards adds, "contain osseous earth, is seen from their whiteness." And one of his followers states, that "these tubes are chiefly rendered visible by means of their contents." How a tube can be filled with osseous matter, and at the same time allow of the circulation of a "nourishing and supporting fluid," I cannot understand. It must not be forgotten, too, that Retzius allows "that, in the tooth, no renovation of the material appears to take place."

Nor is it with respect to the more direct inductions drawn from the tubular system alone, that I must avow myself in some respects at issue with the ingenious and industrious Professor of Stockholm. "When the milk-teeth," he says, "are examined just before they are about to be shed, they are found to present an appearance as if, from pressure of their permanent successors, they had wasted or been absorbed at their roots. The crown of the advancing tooth appears to have pressed itself into the extremity of the deciduous one. I have carefully examined how this appearance is produced, and have come

to the *decided conviction* that neither *tabescence*, *absorption*, nor *erosion* has anything to do with it." This is a statement which may be so easily refuted by the simplest observation, that I need not here waste the time of the reader by entering into a formal demonstration of its fallacy.

With a candour which cannot be too highly praised, Retzius allows that he is ignorant of the specific functions of the tubes in the dental bone of the adult tooth. His ideas on this subject, as might be expected at this early stage of the inquiry, are far from definite. "In common bone, *probably*," says he, "the peculiar vessels in question take a part in the continual, or apparently continual, exchange of substance: this cannot in the same degree be the case in dental bone, inasmuch as in this no such exchange appears to take place. What end then is served by this beautiful organisation of dental bone? We have many examples that nature organises structures which have a close affinity to each other according to one and the same plan, and hence we have, in different parts or organisms, formations, which in some are of the greatest importance, whilst in others they are of much less functional significance, or of *none whatever*. If we hence assume, what is highly *probable*, that in bone the peculiar vessels in question give passage to fluids during the entire life of the animal, (or a great part of it,) which fluids contain the solid as well as the liquid materials of the osseous substance; it does not necessarily follow that the same process must be carried on in the teeth during the whole of life. On the contrary, I am inclined to believe that these vessels in dental bone are at their height during the first period of the formation of the tooth, and exercise then their more perfect action.

At the same time, the existence of a continual vital process in the tooth, as well as in the crystalline lens, cannot be denied, which, however, appears to be carried on without any constant exchange of solid matter, and must hence consist in a renovating circulation." I have quoted this sentence again, because it characterises, more justly than any objections I could make, the imperfect state of the inquiry.

The theory of the tubular system assumed to be true, has been with considerable ingenuity employed by a very eminent naturalist to explain that which takes place when teeth are stopped: it has been said that the mouths of the vessels which have been cut across in this operation deposit a layer of calcareous matter under the *stopping*; but I believe that no facts bearing out this assertion have yet been observed; and I cannot but think that the general character of the tooth, and the nature of the functions which it has to perform, are altogether incompatible with the existence of a system of open-mouthed vessels ready to pour out fluid of any kind to a greater or less extent. It is well known that even the least increment, or change of the material of the tooth under the stopping, renders that operation quite ineffectual, either by displacing the stopping, or by admitting the fluids of the mouth, and thus promoting decomposition beneath it.

I may here remark, that the intelligent professor of Stockholm states that the crusta petrosa ceases at the neck of the tooth in many animals in which it is in fact continued over the whole extent of the enamel. The views of Müller on the crusta petrosa are very erroneous. "This new substance, the cement, or crusta petrosa," he says, "seems to be merely a deposit from the salts of the saliva, and to be essentially the same as what is called *the*

tartar of the human teeth." (Müller's Phys., translated by Dr. Baly.) A simple examination of the organised structure of the cement by means of the microscope is sufficient to convince any one of the fallacy of this statement. See Plate C. 4.

Retzius states that only three substances enter into the composition of the teeth in their various forms, viz. ivory, enamel, and cement; but I think that a fourth ought to to be added to this list, viz. a structure having the appearance of ossified pulp, in which the vessels seem to retain their original position, but are found in a state of atrophy, intermingled occasionally with irregularly-formed ivory. This substance may be considered as constant as any of the other three: it constitutes almost exclusively the simplest teeth, as those of the ornithorynchus,* anarrhichas lupus,† &c.; and it is occasionally found to enter into the composition of the teeth of almost every animal, either normally, as in the walrus,‡ bradypus, orycteropus,§ ptychodus polygyrus,|| &c., or abnormally, as in some human teeth. It also often presents itself in the diseased tusks of the elephant, a drawing of which is given in Plate C. 3, Fig. 2. *c*, where it is contrasted with its normal appearance in the walrus.

A detailed account of my own opinions and researches on the structure of the teeth the reader will find in the body of the work. The above remarks I offer more to justify myself for not fully and at once agreeing with all the positions laid down by those who have written on the dental tubes, than with the intention of directly refuting

* See Plate C. 1. Fig. 1. † See Plate C. 1. Fig. 2 and 3.
‡ See Plate C. 3. Fig. 1. *c*.
§ See Plate C. 1. Fig. 5. and 6. *a. a.*
|| See Plate C. 2. Fig. 1. and 2. *a. a.*

or denying them. All that I wish to do at present is, to show that further research, more varied experiments, and a more rigid examination of the subject in all its departments and bearings, are absolutely required before the doctrine of a tubular system can be considered as immutably established.

The sketch which I have given of the progress of information in this department of science shows that many interesting branches of the subject are still uncultivated, and that, though many remarkable points connected with the structure have recently been started, mechanical analysis alone has been resorted to for their elucidation, and that, too, as I have already mentioned, without sufficient attention to the nature of the structures submitted to observation, or to the kind of manipulations adopted for their preparation. I feel confident that even the method of mechanical analysis hitherto pursued is still capable of great improvement, and that it would have been considerably modified by Professor Retzius, had he been able to devote further attention to the subject. Having commenced my experiments where his terminate, I think I may say that a year and a half's constant attention to the subject has much improved and facilitated my means of observation, and has led me to new and important results. One of the greatest chemists of the present day has promised me an analysis of the structures entering into the composition of the teeth throughout the range of the animal kingdom, which when completed will furnish a valuable accession to our knowledge of these organs. I have also myself had recourse to chemical decomposition, which has yielded me no little assistance in unravelling the texture of these organs.

EXPLANATION OF THE PLATES

COMPREHENDED IN SERIES A.

The three Plates A. 1, A. 2, and A. 3, are exact copies of those given by Retzius to illustrate his views of the structure of the teeth, and are referred to in the account of his researches contained in the Historical Introduction. The illustrations are the same in the Stockholm edition of his work, as in the account given in Müller's Archiv. for 1837. I have preferred copying them from the latter, as they appear rather better executed than those accompanying the former. The explanation given by him of these appearances is as follows :—

Plate A. Fig. 1.—" The fibres of the enamel viewed sideways under a magnifying power of three hundred and fifty times. *a a a a a*, the enamel-fibres; *b b b b*, the transverse stripes upon them."

Plate A. 1, Fig. 2.—" A vertical section of an adult human bicuspis, cut in a direction from without inwards; magnified four times its natural size. *a a*. The cortical substance which surrounds the root up to the commencement of the enamel. *b b*. The ivory of the tooth, in which are

seen the greater parallel curvatures, as well as the position of the main tubes. *c.* The apex of the tooth where the tubes are almost perpendicular. *d d.* The enamel. *e e.* The cavity of the pulp, in which are seen, by means of a magnifying glass, the openings of the tubes of the dental bone."

Plate A. 1, Fig. 3.—" A vertical section of an imperfectly developed human incisor, taken from the follicle in which it was still enclosed. This section is meant to show the position of the enamel-fibres, and also to demonstrate that a *part* of the appearances which are seen in this substance under a less magnifying power originate in parallel curvatures of the fibres. *a a a.* The enamel. *b b.* The tooth-bone or ivory.† *d d.* The minute indentations and points on the surface of the ivory on which the enamel-fibres rest. *e e.* Brown parallel stripes; *e** parallel flexions of the fibres of the dental bone in these stripes."

Plate A. 1, Fig. 4.—" A portion of the surface of the enamel, on which the hexagonal terminatious of the fibres are shown. *a a a.* Two more strongly marked dark crooked crevices running between the rows of the hexagonal fibres."

Plate A. 1, Fig. 5.—" A small portion of fig. 2, covered with turpentine varnish, viewed under a magnifying power of three hundred and fifty times. It is seen that the tubes *a a a a a a* contain a powdery lumpy substance. They are regular and closely undulating; the branches do not appear, because they are penetrated by the varnish.

Plate A. 1, Fig. 6.—" A transverse section of the crown of fig. 2, in which the upper end of the cavity of the pulp

* In the plate one *b* is erroneously placed on the enamel.

has been cut off; viewed under a low magnifying power; the main tubes which are nearest the cavity being transversely cut, and the more external ones cut in an oblique direction."

Plate A. 1, Fig. 7.—" A small portion of the same section viewed under a magnifying power of three hundred and fifty times. On the right side are seen the round openings of the tubes *e e e*, *f f*, with parietes of a peculiar substance. The tubes on the left hand side *h h*, *i i*, *a a*, are obliquely cut in consequence of their more external position."

Plate A. 1. Fig. 8.—" The position of the same main tubes in a transverse section magnified five times, near the root of a bicuspis. The dark patches in this figure mark the places in which the bone was especially white and less transparent than in the clearer intermediate tracts."

Plate A. 1, Fig. 9.—" A transverse section taken from near the root of a canine tooth of an elderly person, which had a covering of cortical substance unusually thick. *a.* The cavitas pulpæ. *b.* The tooth-bone. *c.* The cortical substance."

Plate A. 1, Fig. 10.—" A molar tooth of an old cow, covered entirely with cortical substance, which has been partly removed; this cortical covering increases in thickness towards the root. *a.* The enamel. *b b.* The cortical substance."

Plate A. 2, and Plate A. 3, " represent the tubes of the dental bone considerably magnified, with the various ways in which they ramify in different animals." (These two plates are executed on a dark ground in Retzius' work, but as there seemed to be no advantage derived from that arrangement, they have been done in the usual manner.)

Plate A. 2, Fig. 1, *a*. "The most interior portion of the tubes of the dental bone in an incisor of a child two years old, close to their commencement in the cavitas pulpæ, in order to show their first division.

Plate A. 2, Fig. 1, *b*.—" The external portion of the tubes of the same tooth, exhibiting their more minute ramifications, which, for the most part, turn towards the crown."

Plate A. 2, Fig. 2, *a*.—" The external portion of the tubes of the dental bone in the incisor of the hare."

Plate A. 2, Fig. 2, *b*.—" A single main tube of the same tooth."

Plate A. 2, Fig. 3.—" A main tube, with its branches in the tooth of the Squalus Cornubicus."

Plate A. 3. Fig. 4.—" The tubes of the dental bone in the tooth of a Delphinus Delphis, near the cavitas pulpæ, showing a group of irregular larger osseous cells and anastomoses in one of the oval spots, which, as it were, has pushed aside the regular main tubes. Similar irregular groups of cells are seen in the teeth of several mammalia, and even in the centre of human teeth where the cavity is filled with ossific matter."

Plate A. 3, Fig. 5.—" The tubes of the dental bone in the Python Bivittatus, the branches of which are given off from that side of the main tubes which is turned towards the root of the tooth."

Plate A. 3, Fig. 6.—" The external part of the tubes of the dental bone in the incisor of an adult Horse, showing the numerous cells into which the minute terminations of the tubes finally enter. The closely-placed cells form the fine concentric parallel lines in this dental bone."

EXPLANATION OF THE PLATES

COMPREHENDED IN SERIES C,

ILLUSTRATING THE STRUCTURE OF THE TEETH.

PLATE C. 1, Fig. 1.—A transverse section of the tooth of the *Ornithorynchus Paradoxus*, viewed under a magnifying power of half-inch focus. A vertical section is not given of this tooth, as the structure is not distinct in that aspect. It seems to be furthest removed, both in its minute structure and general character, from the teeth of the higher animals, and resembles horn, both in appearance, texture, and chemical properties.

PLATE C. 1, Figs. 2 and 3.—A transverse and vertical section of the tooth of the *Anarrhichas Lupus*, both viewed under a magnifying power of half-inch focal distance. This may be considered as an example of one of the simplest structures. The principal portion of the tooth is seen to present the appearance of the pulp converted into an ossific structure. *b b*. The vessels appearing to retain their original situations. There is only a very thin layer of ivory externally, *a a*.

This texture is generally worn away by attrition from the top of the tooth, as is seen in the specimen.

Plate C. 1, Fig. 4, 5, and 6.—Three sections of the tooth of the *Orycteropus Capensis.* Fig. 4 is a transverse, and Fig. 6 is a vertical section, both as viewed by means of a magnifying power of half-inch focal distance; and Fig. 5 is a highly magnified portion of the transverse section, as seen under a magnifying power of one-tenth of an inch focal distance. The structure of this tooth shows the difficulty of classifying the objects of natural history. It has generally been classed among the teeth of the simplest structure, whereas, when rightly considered, it is a very curious and interesting example of a complicated structure. Processes of the pulp in an ossified state are present in the centre of each lozenge-shaped compartment, as seen in the transverse section, Fig. 6, *a a a*, and may be observed more particularly in the centre of the highly-magnified portion of the same, Fig. 5, *a*. The external surface of the whole tooth is enveloped in a comparatively thick investment of crusta petrosa, as seen at *a a*, Fig. 4. *b b*, Fig. 4, is the ivory portion of the tooth. *b b*, Fig. 6, and *b b*, Fig. 5, mark the peripheral portion of the compartments where corpuscules are seen as in the crusta petrosa.

Plate C. 2 contains sections of the tooth of the *Ptychodus Polygyrus.* Figs. 1 and 2 are viewed by means of a magnifying power of half an inch focal distance, and Fig. 3 by means of one-tenth of an inch focal distance. The structure of this fossil-tooth is somewhat similar to that of the Orycteropus, but not so regular. At *a a*, Fig. 2, are seen the small compartments in the centre of which is the ossified pulp. Fig. 2 *c* marks the situation of the small portion which is highly magnified at Fig. 3. At

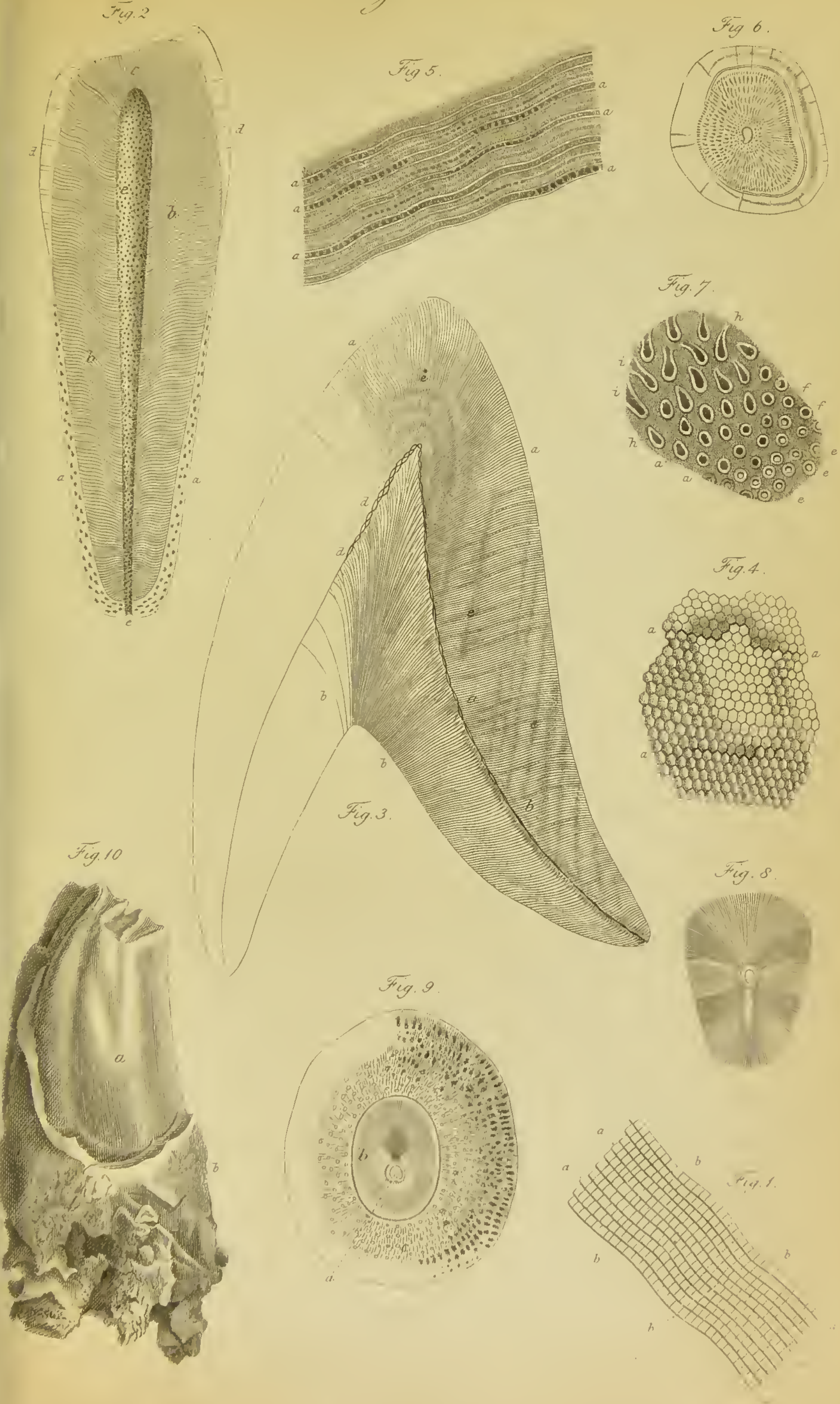
Fig. 1, *a a*, are seen the ossified centres of the compartments: *b b*, the ivory. Fig. 3 is a portion of the transverse section given in Fig. 2, and taken from the situation marked *c* in the latter. Fig. 4 is meant merely to show the general appearance of the tooth.

Plate C. 3, Fig. 1.—A vertical section of the tooth of the Walrus, as viewed by means of a magnifying power of one inch focal distance. This tooth consists of crusta petrosa *a*, ivory *b*, and ossified pulp *c*, intermingled with irregularly formed ivory.

Plate C. 3, Fig. 2.—A section of a tusk of the *Elephant*, as viewed by means of a magnifying power of one inch focal distance, where disease has greatly affected the formation of the structure of the ivory, and produced an appearance, as seen at *c*, similar to that which is normally found in the walrus. It is curious to remark that the commencement *d* of this irregular portion is defined by a layer containing corpuscules, such as are seen in the crusta petrosa; *a* is the crusta petrosa, *b* the ivory.

Plate C. 4, contains various sections of different portions of the *crusta petrosa* of the elephant's grinder, as seen by means of a magnifying power of one inch focal distance, displaying the organisation of that structure, the resemblance of which to true bone is very evident. The two first sections, Figs. 1 and 2, are from the portions of crusta petrosa, which fill up the lateral convolutions of the tooth. Figure 3 shows the beautiful arrangement of the other portions of the tooth in connexion with the crusta petrosa; *a* the crusta petrosa, *b b* the ivory, and *c c* the enamel. Fig. 4, a highly magnified portion of the vertical section, showing the disposition and appearance of the corpuscules.

Retzius' Plates



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Retzius' Plates.

Fig. 1. a

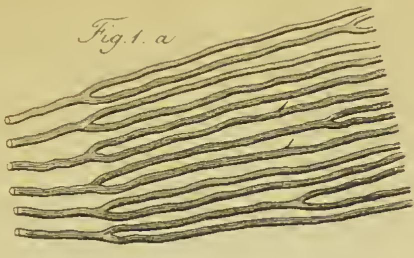

Fig. 1. b.

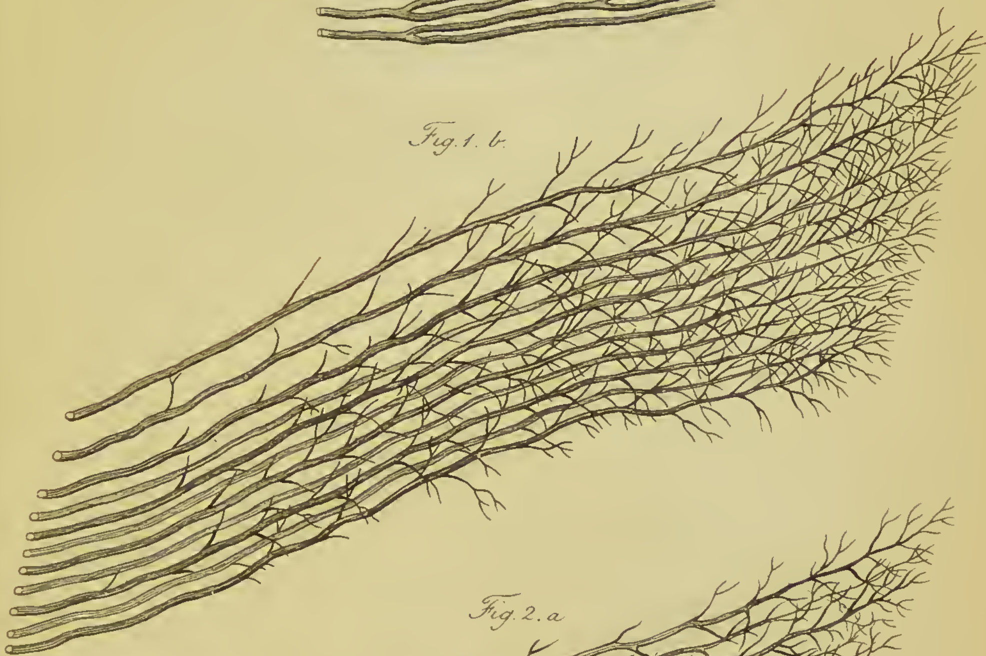

Fig. 2. a

Fig. 2. b.

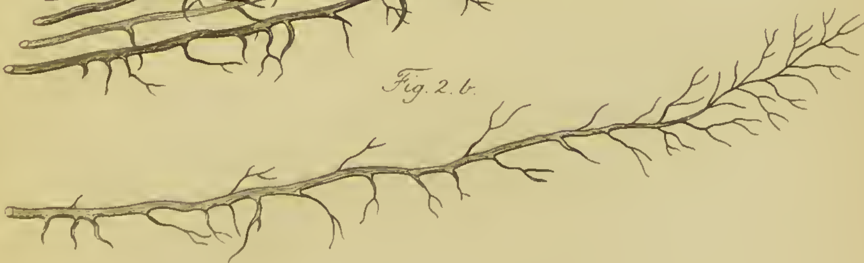

Fig. 3.

J. W. Lowry, sculp.

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Fig 5.

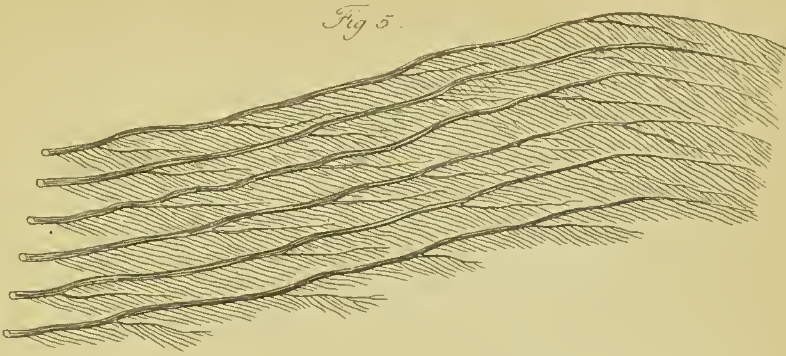

Fig. 6.

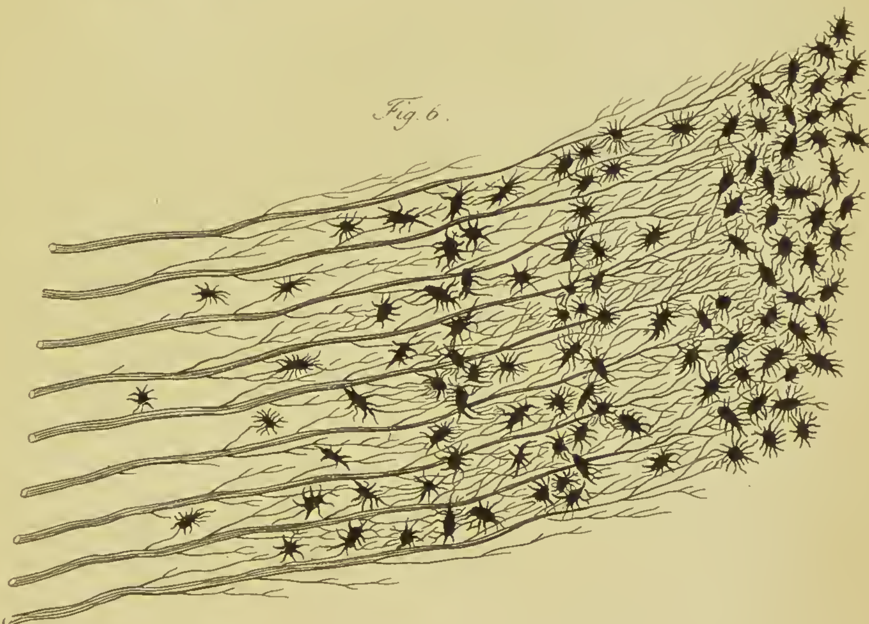

Fig. 4.

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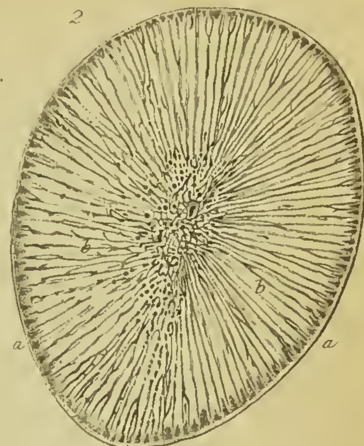
Structure of the Teeth.

1

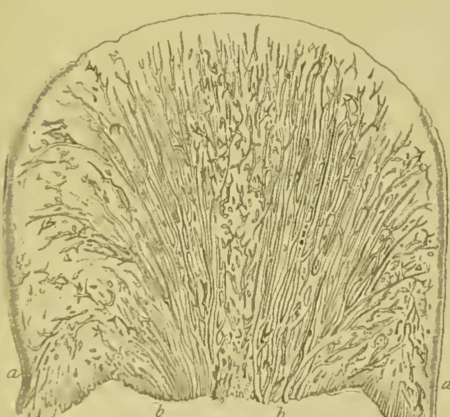
Ornithorynchus Paradoxus.
Transverse section.

2



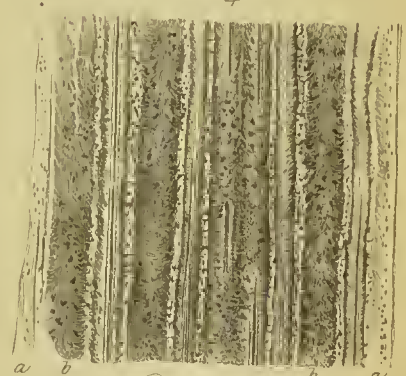
Anarrhichas Lupus.
Transverse section.

3



Anarrhichas Lupus.
Vertical section.

4

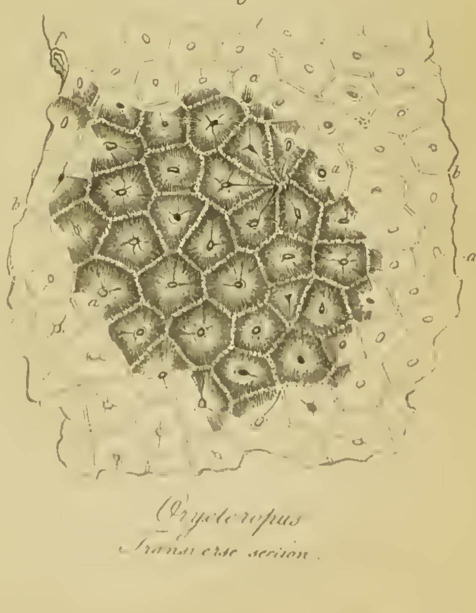


Orycteropus.
Vertical section.

5

Orycteropus.
Portion of transverse section highly magnified.

6



Orycteropus
Transverse section.

Mr Holmes delin.

J.W. ...sey. sculp.

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Ptychodus Polygyrus.

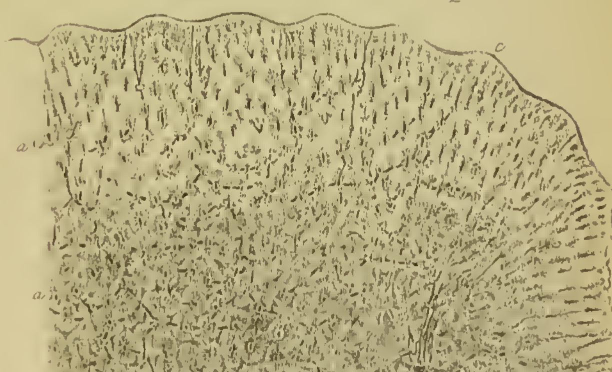
1

Vertical section.

3

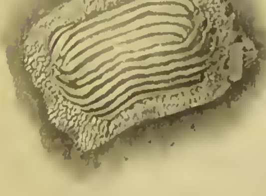
Highly magnified portion of transverse section at c

Transverse section. 2



4

Ptychodus Polygyrus. Natural size.



Helmes, delin

J W Leary

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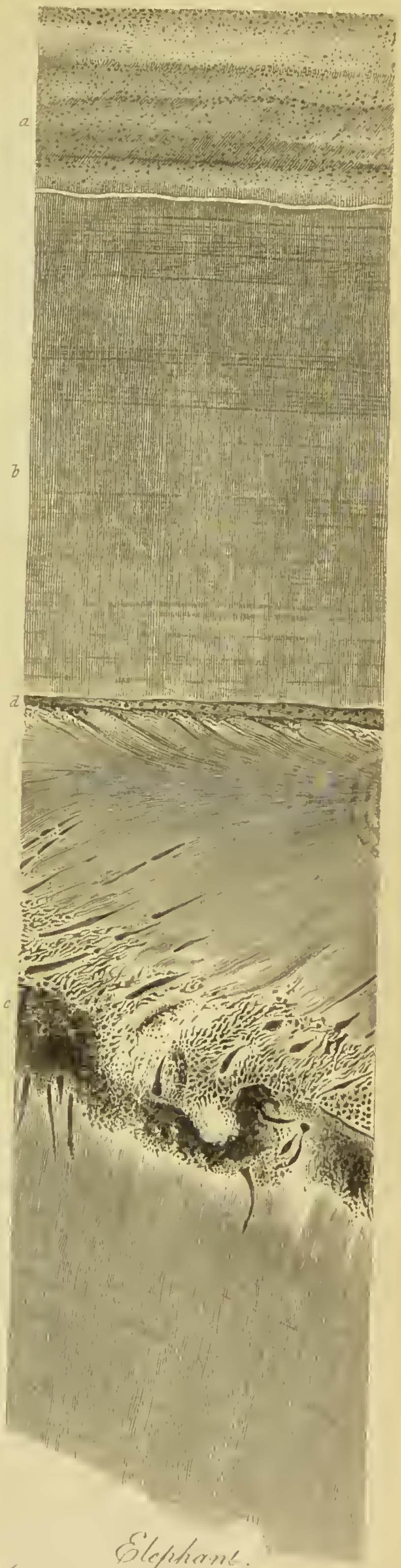
Structure of the Teeth.

1

Walrus
Vertical section of tusk.

2



Elephant.
Appearance presented by a diseased tusk.

Wm. Holmes delin.

London John Churchill Princes Street Soho

J. R. [illegible] sculp.

Structure of the Teeth.

Elephant.

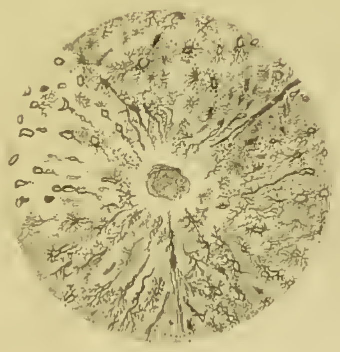
Crusta petrosa of grinder.

1 Vertical section of external portion

2 Transverse section of external portion.

4

Magnified portion



of Vertical section

3

Transverse section of internal portion included between the enamel

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